

# **Microwave Temperature Profiler (MTP) Status Report**

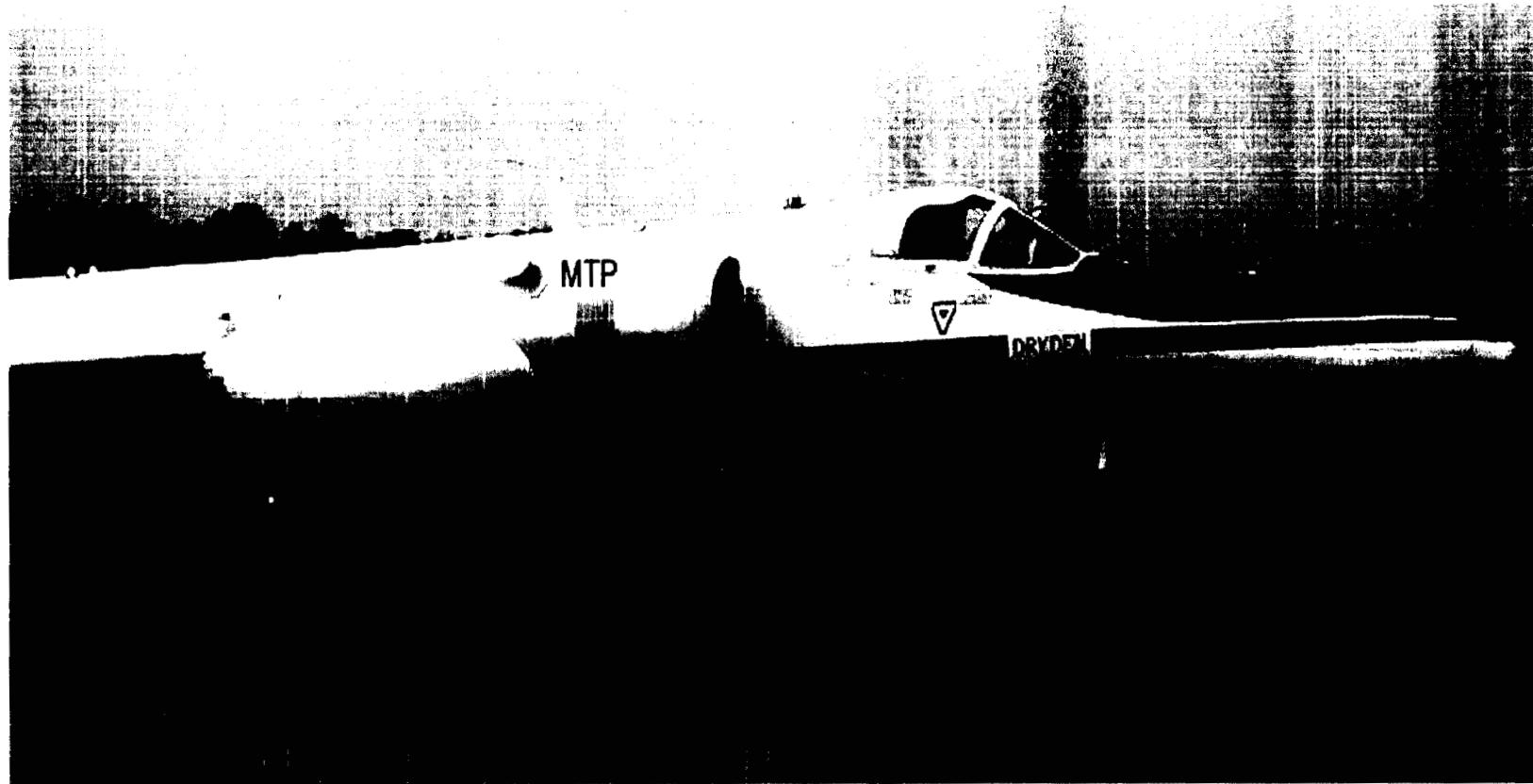
**MJ Mahoney**

**CAMEX-4 Workshop**

**New Orleans, LA**

**March 13 -15, 2002**

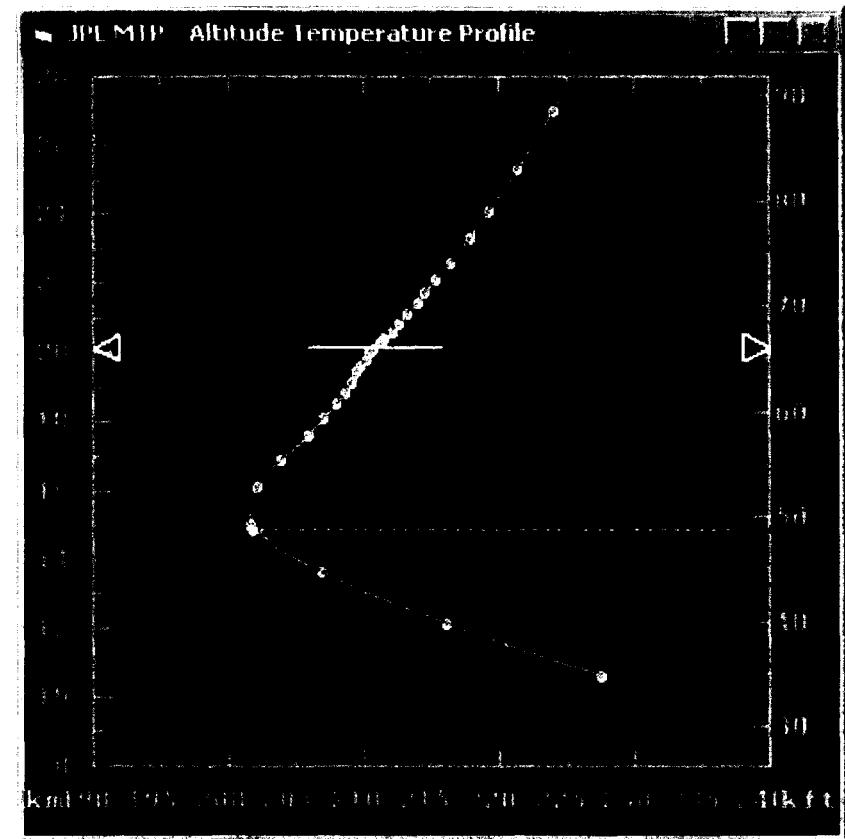
# ER-2 Microwave Temperature Profiler (MTP)



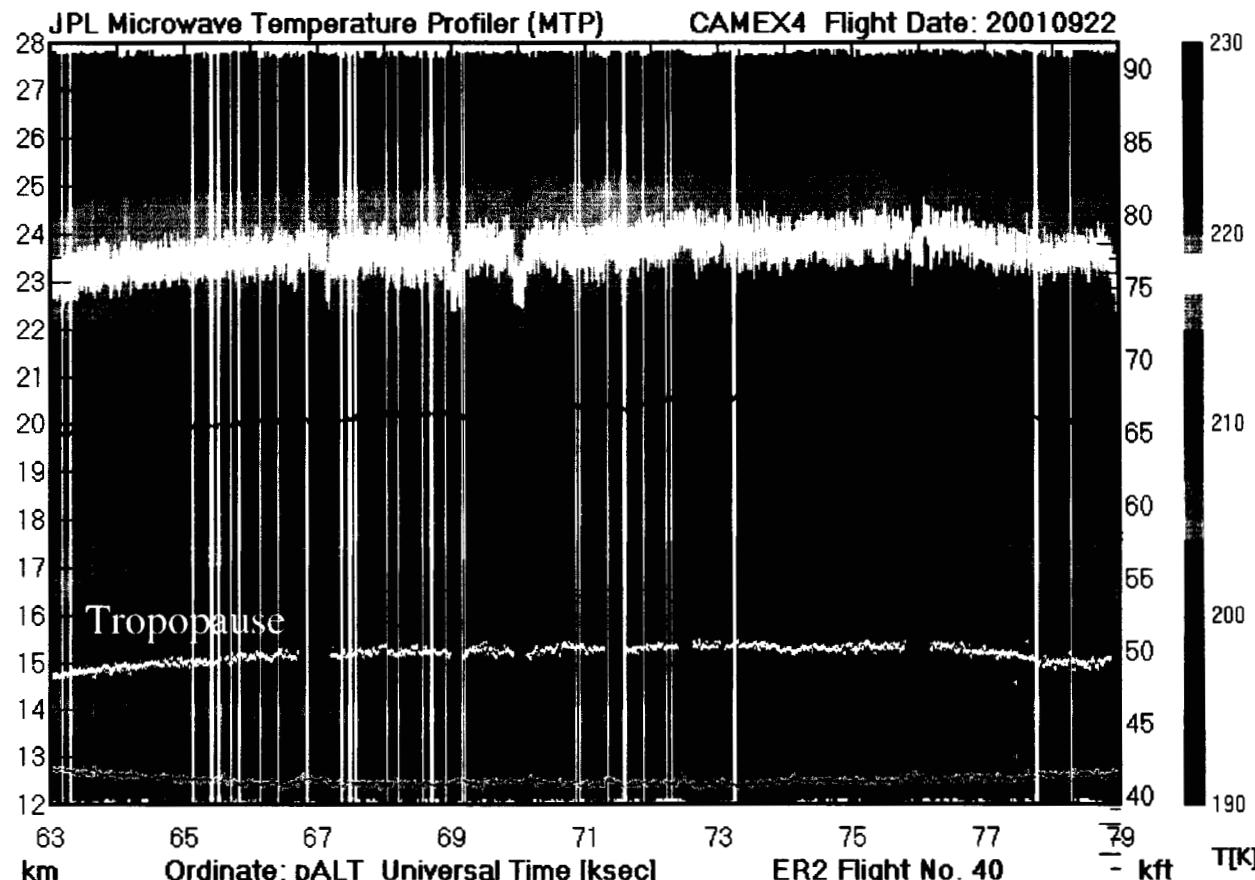
- PI: MJ Mahoney, Jet Propulsion Laboratory, California Institute of Technology
- MTP measures the temperature profile above, below & at flight level by observing the natural thermal emission from oxygen molecules between 55 and 59 GHz
- MTP Heritage: >500 Flights (>3000 Flight Hours)
- MTP Sensor Unit and Data Unit are located on right engine cheek (see figure)

# Microwave Temperature Profiler (MTP)

- Derived geophysical products:
  - Temperature profiles along the flight track
    - Tropopause altitude
    - Lapse Rate
    - Isentrope ( $\theta$ ) surfaces
- Science objectives
  - Provide mesoscale meteorological context for *in situ* measurements
  - Assimilate into meteorological models
  - Use derived isentrope surfaces to study dynamical phenomena
- Data availability and analysis plan
  - Within <1 hour after data taken from a/c
  - Final data within 6 months of end of deployment



# ER-2 Microwave Temperature Profiler (MTP)



**PRELIMINARY DATA** Principal Investigator: MJ Mahoney ([Michael.J.Mahoney@JPL.NASA.GOV](mailto:Michael.J.Mahoney@JPL.NASA.GOV)) **PRELIMINARY DATA**  
History: Flight: 2001 09 22 00:00:00 Retrieved: 2001 09 23 00:29:12 Edited: 2001 09 23 00:38:22 Plotted: 2001 09-23 00:39:04

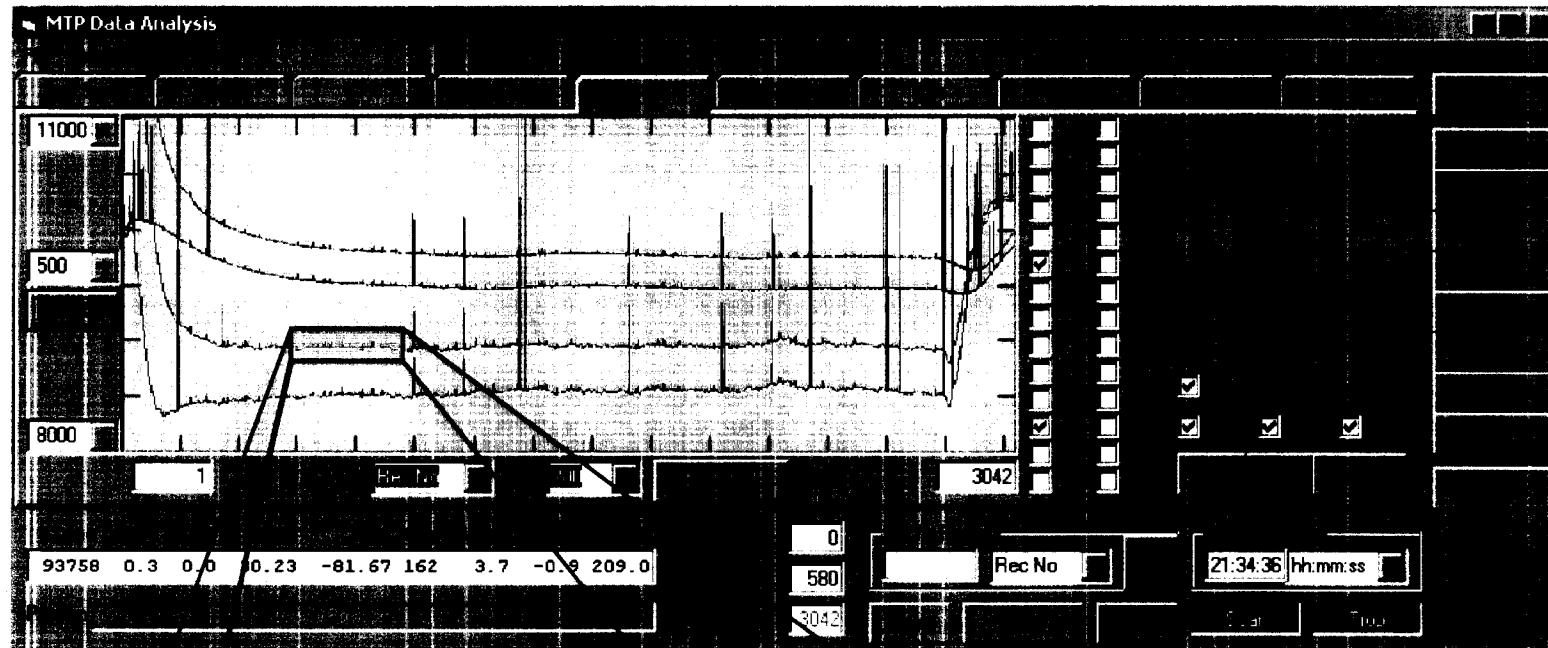
An example of a MTP-derived temperature field along ER-2 flight track over TS Humberto during CAMEX-4. Black trace is ER-2 pressure altitude, and white trace is the tropopause altitude. The temperature scale is color-encoded in the bar to the right from 190-230 K. Vertical white stripes are data edited out because of radio frequency interference.

# **Microwave Temperature Profiler (MTP) Status**

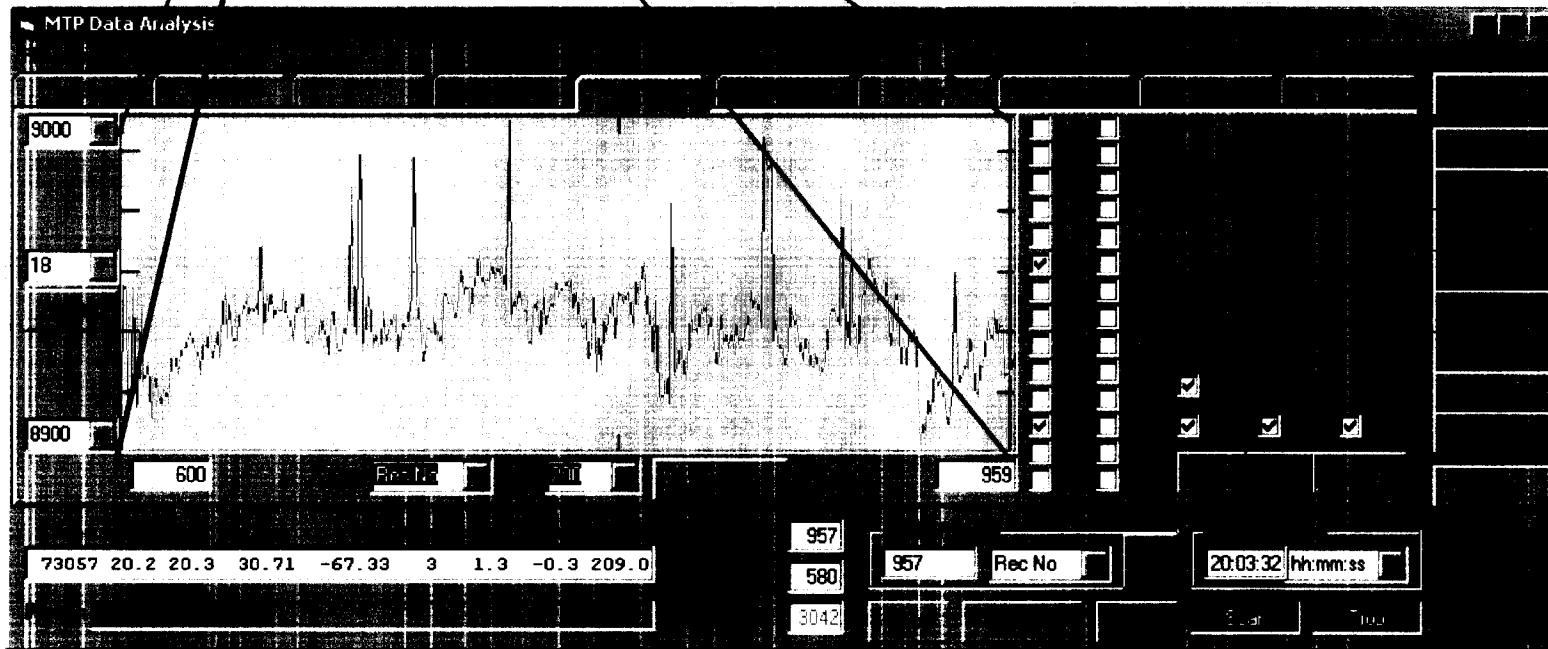
## **Report on ER-2 MTP Data and Data Analysis**

- Heavy & weak interference - typically 20-25% of each flight

# An Example of Interference Seen on an ER-2 CAMEX-4 Flight



Entire Flight  
Vertical Tic  
~25 K



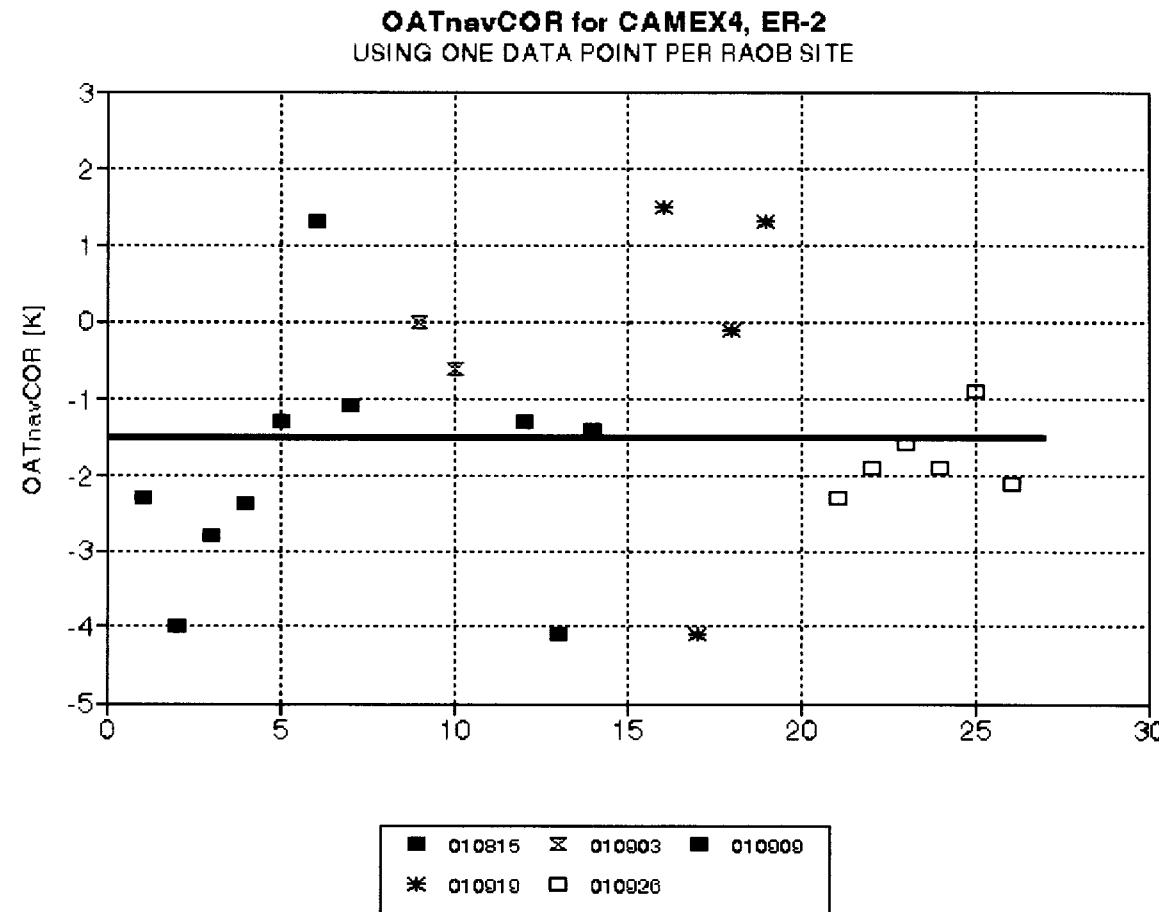
25-X Zoom  
Vertical Tic  
~1 K

# **Microwave Temperature Profiler (MTP) Status**

## **Report on ER-2 MTP Data and Data Analysis**

- Heavy & weak interference - typically 20-25% of each flight
- Nav Data Recorder Outside Air Temperature is *too warm*
  - Based on RAOB comparisons, the required correction is:  $-1.51 \pm 0.36$  K

# ER-2 Nav Data Recorder Temperature Calibration



- Thirty-one (31) RAOB comparisons in total from five CAMEX-4 ER-2 flights
- Passes over the same site were averaged unless the altitude differed by >1.5 km
- Result is that OAT<sub>nav</sub> is too warm, correction =  $-1.51 \pm 0.36$  (N=22)

# Microwave Temperature Profiler (MTP) Status

## Report on ER-2 MTP Data and Data Analysis

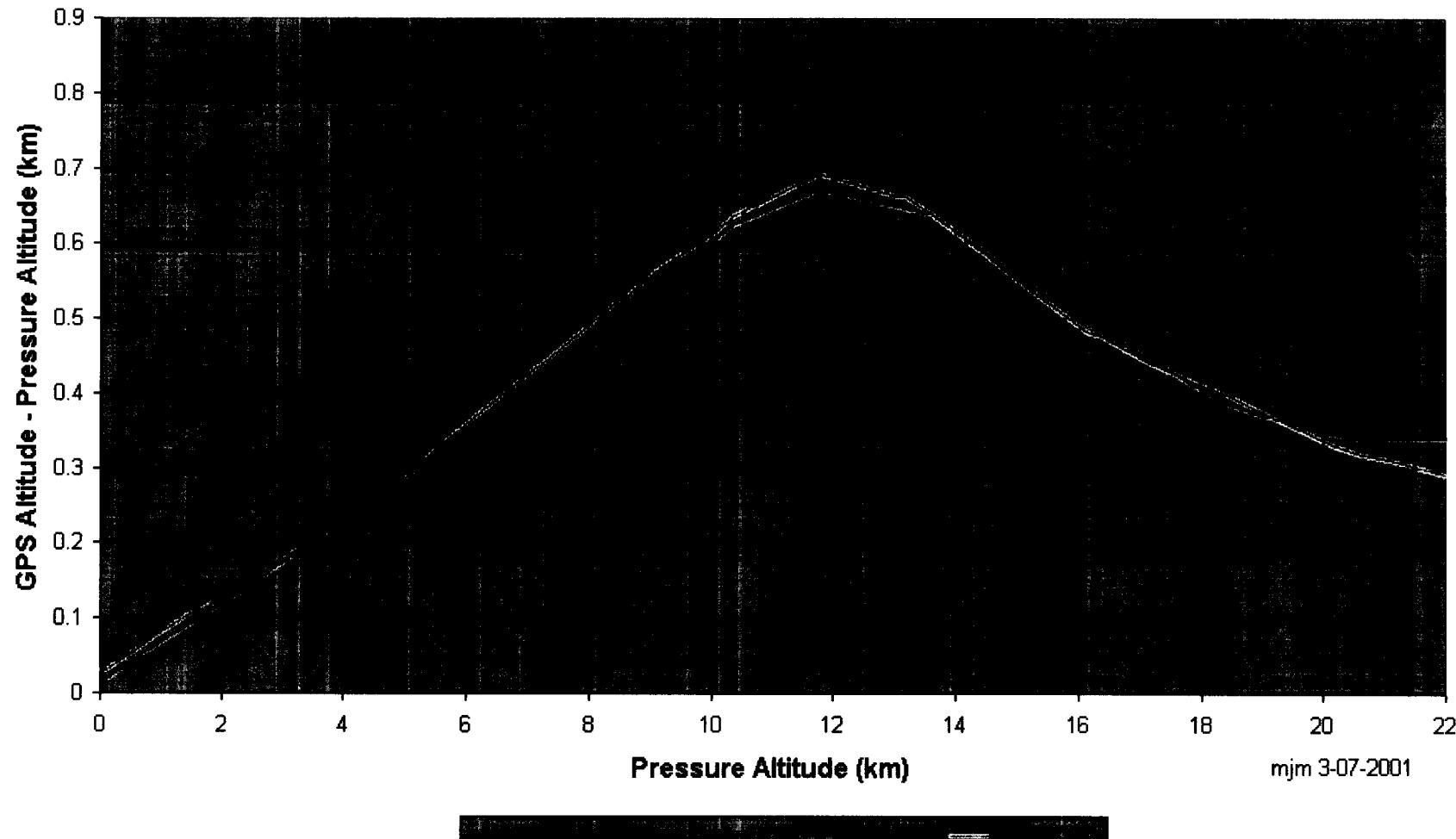
- Heavy & weak interference - typically 20-25% of each flight
- Nav Data Recorder Outside Air Temperature is *too warm*
  - Based on RAOB comparisons, the required correction is:  $-1.51 \pm 0.36$  K
- Nav Data Recorder (NDR) Pressure Altitude (Zp) is *too low*
  - The error is 400-600 meters (~3-5 hPa) at 21 km
  - Procedure developed to reduce this error to <100 meters
  - Impact is to increase MTP retrieval error significantly if error is >100 meters

[http://mtp.jpl.nasa.gov/ER2/ER2\\_MTP\\_Status\\_Report.html](http://mtp.jpl.nasa.gov/ER2/ER2_MTP_Status_Report.html)

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## Comparison of ER-2 GPS and Pressure Altitudes with EYW RAOBs for 2001.09.09

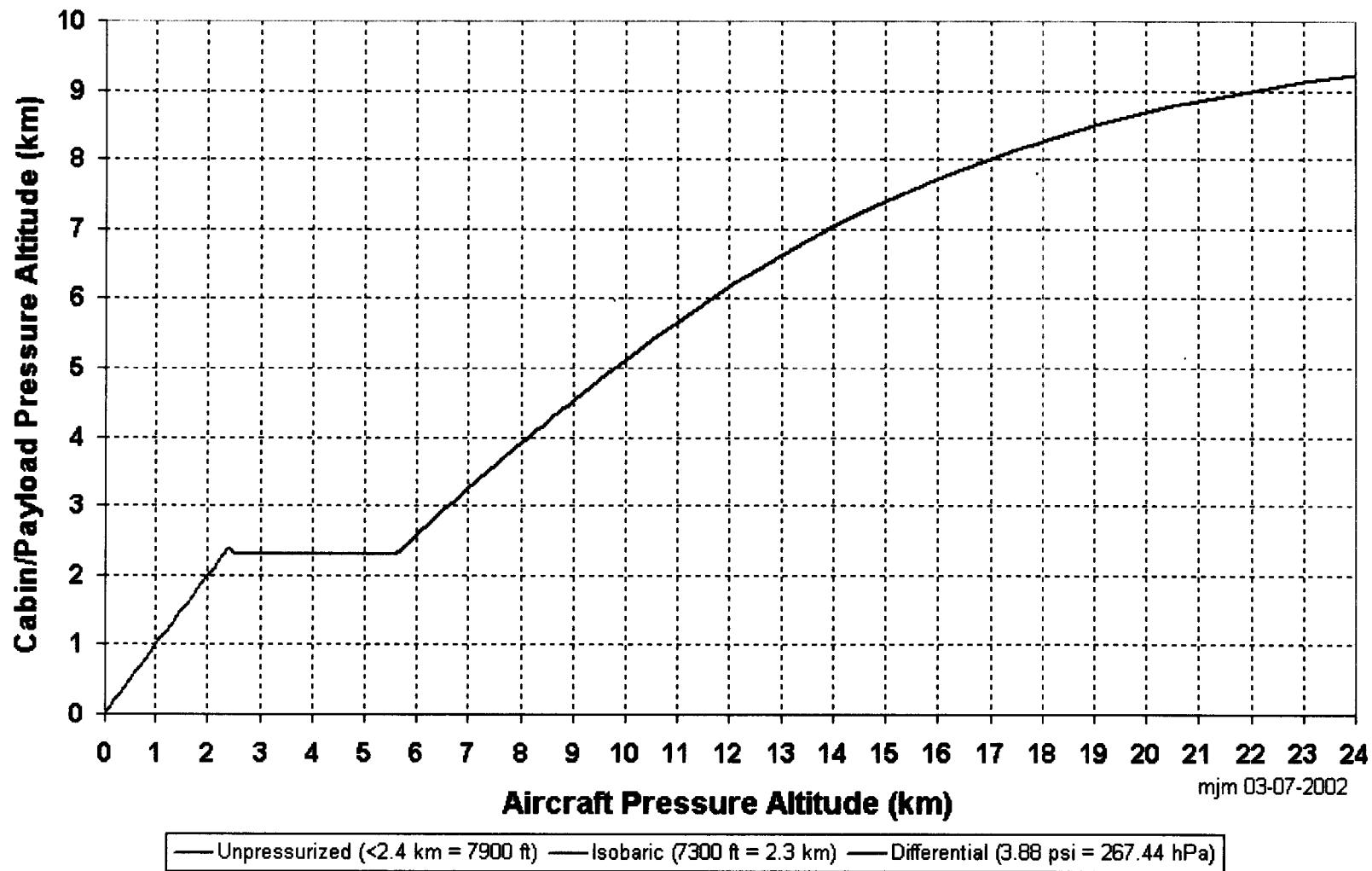
MTP



An Example of the Erroneous ER-2 Nav Data Recorder Pressure Altitude

- Note that error is larger on descent than on ascent
- A large discontinuity occurs at ~8.5 km when switching from fine to course sensor

# ER-2 Microwave Temperature Profiler (MTP)



The ER-2 Environmental Control System (ECS) Pressure Profile

- ECS is under differential control mode for useful Zp (green)

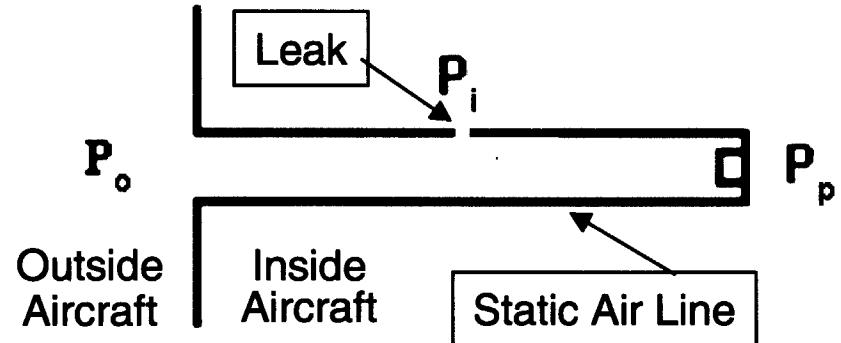
# ER-2 Microwave Temperature Profiler (MTP)

## A Model for a Static Pressure Leak

Under perfect ECS differential control mode:

$$P_i - P_o = 3.88 \text{ psi} = 267.44 \text{ hPa}$$

Therefore, a leak will produce a constant increase,  $P_{corr}$ , in the measured pressure  $P_p$ .



In addition, due to the finite response time of the ECS, there is a temporal correction,  $UT_{corr}$ :

- On ascent,  $P_i - P_o > 3.88 \text{ psi} + P_{corr}$ 
  - Therefore, the pressure altitude ( $Z_p$ ) is even further under-estimated
- On descent,  $P_i - P_o < 3.88 \text{ psi} + P_{corr}$ 
  - Therefore, the pressure altitude ( $Z_p$ ) is even further over-estimated

## Equation to correct NDR pressure altitude, $Z'p$ :

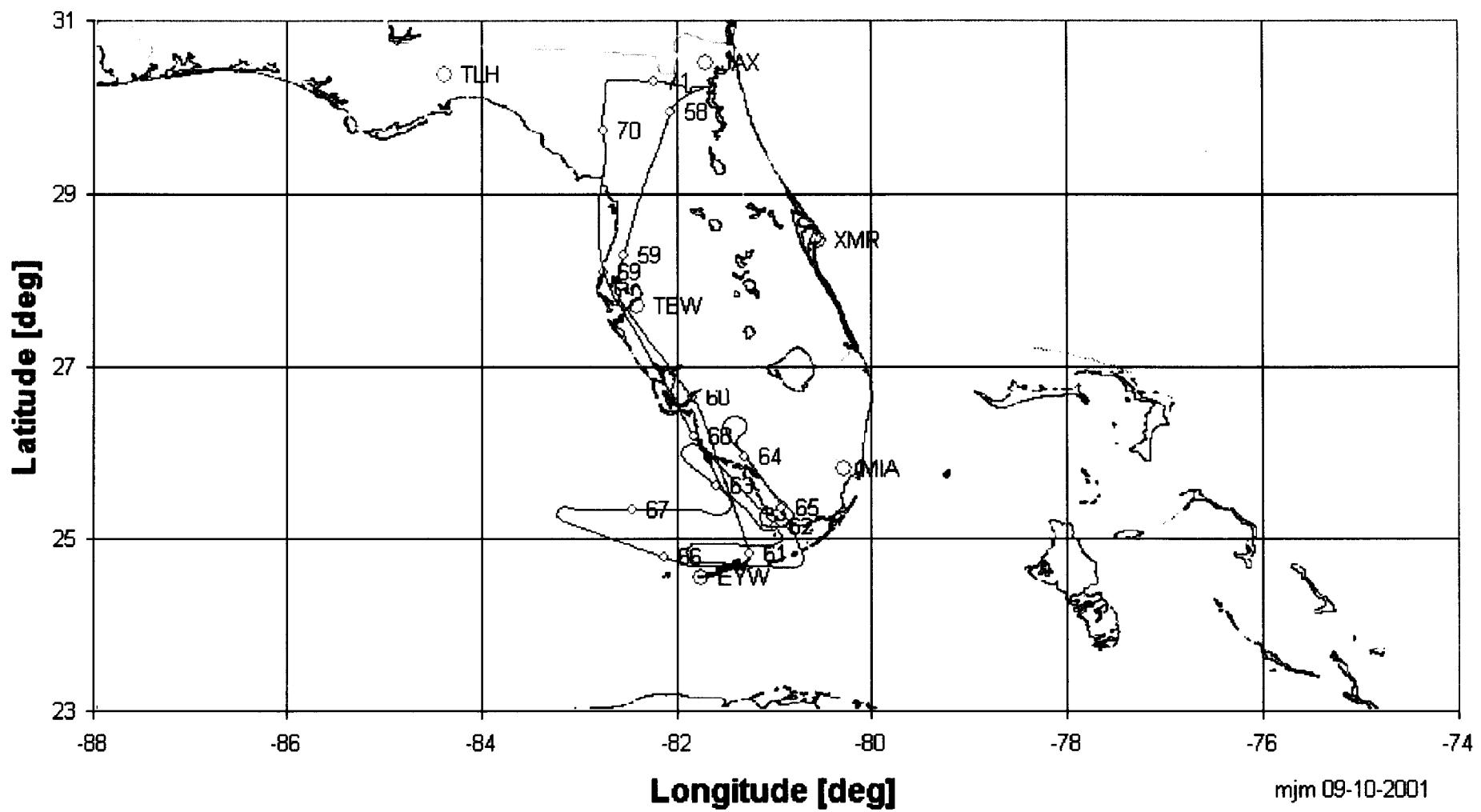
$$Z'p(\text{km}) = fPtoZ( fZtoP(Z_p) + P_{corr} ) + UT_{corr}( UT - UT_{takeoff} )/3600 + Z_{offset}$$

where  $Z_p$  is in km;  $UT$  is in seconds;  $P_{corr}$ ,  $UT_{corr}$ , and  $Z_{offset}$  vary from flight to flight; and the functions  $fPtoZ(p)$  and  $fZtoP(Z)$  convert between pressure and pressure altitude.

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Flight Track - Latitude vs Longitude  
CAMEX4 - ER2 20010909

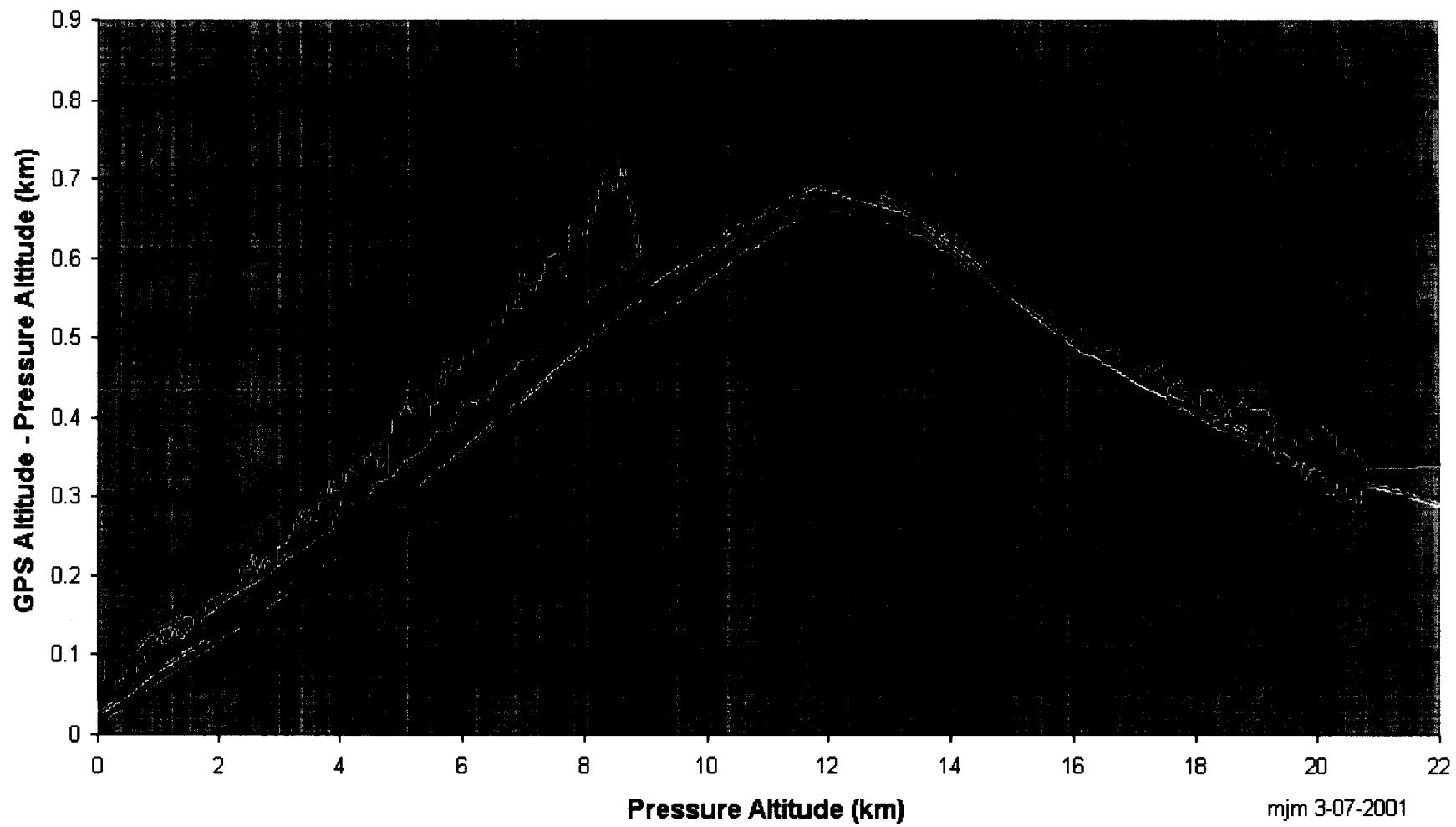
MTP



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## Comparison of ER-2 GPS and Pressure Altitudes with EYW RAOBs for 2001.09.09

MTP



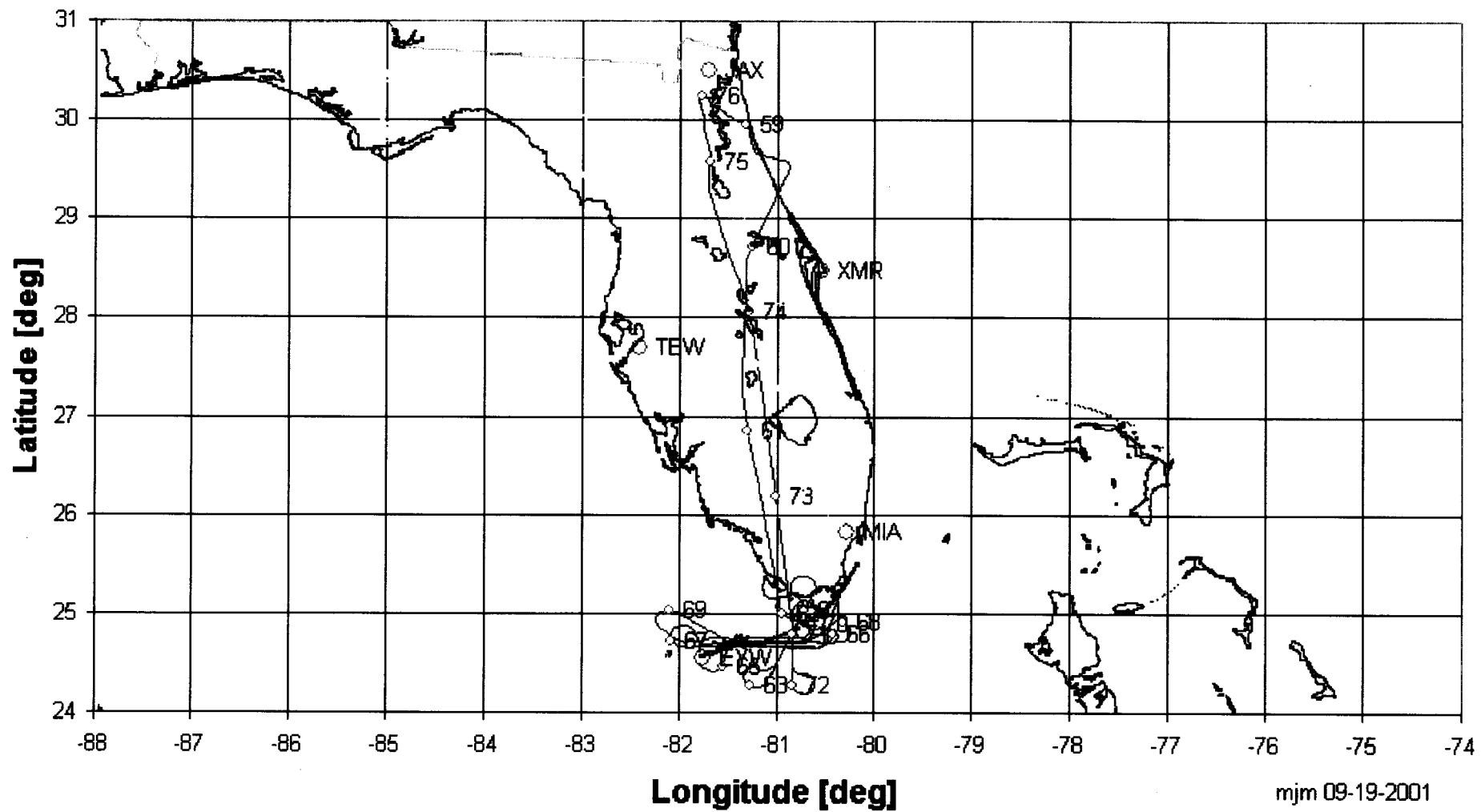
Model for pressure leak does an excellent job of correcting error (orange)

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## Flight Track - Latitude vs Longitude

CAMEX4 - ER2 20010919

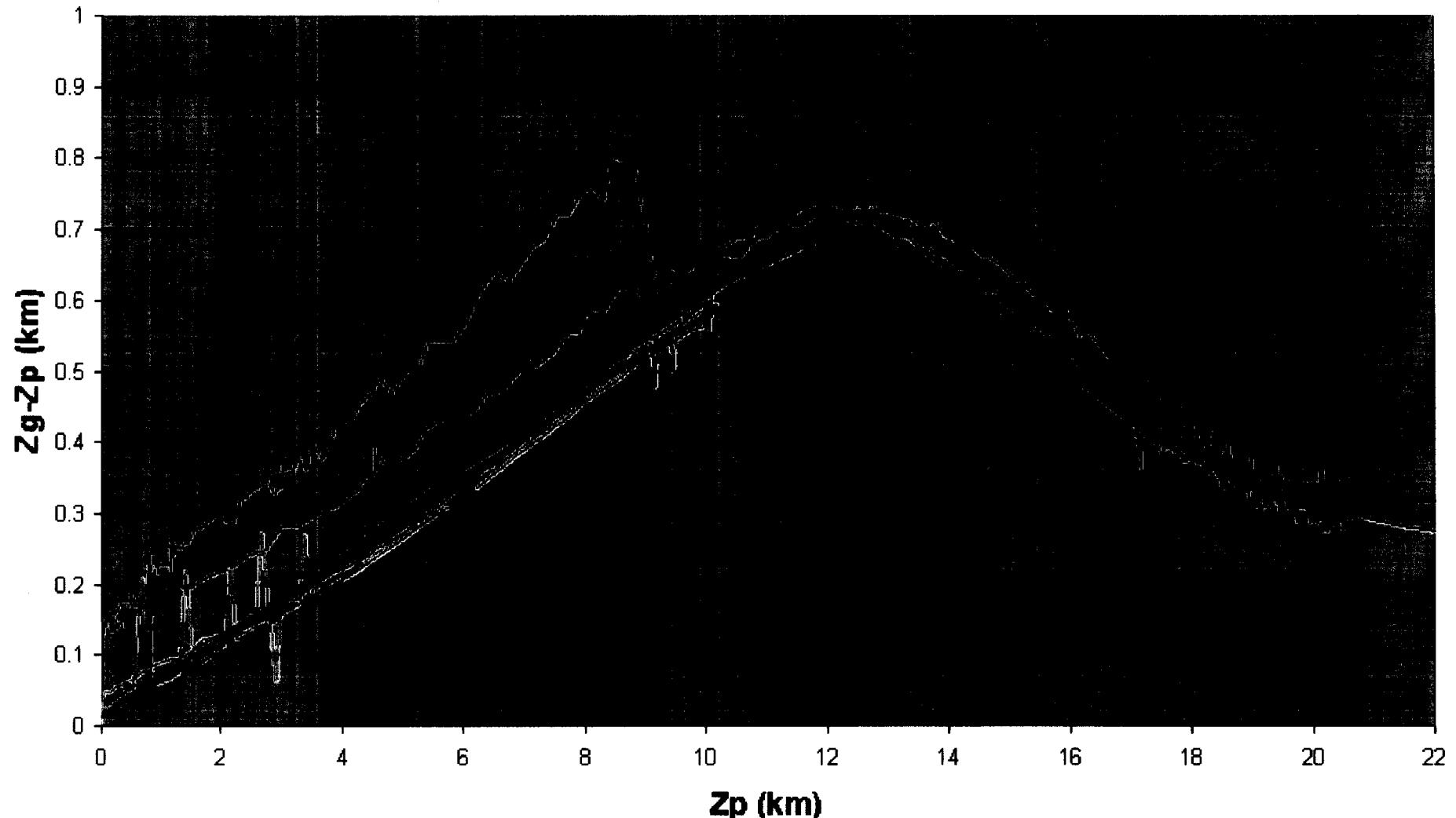
MTP



mjm 09-19-2001

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## CAMEX-4 ER-2 Flight of 2001.09.19 over Key West, FL

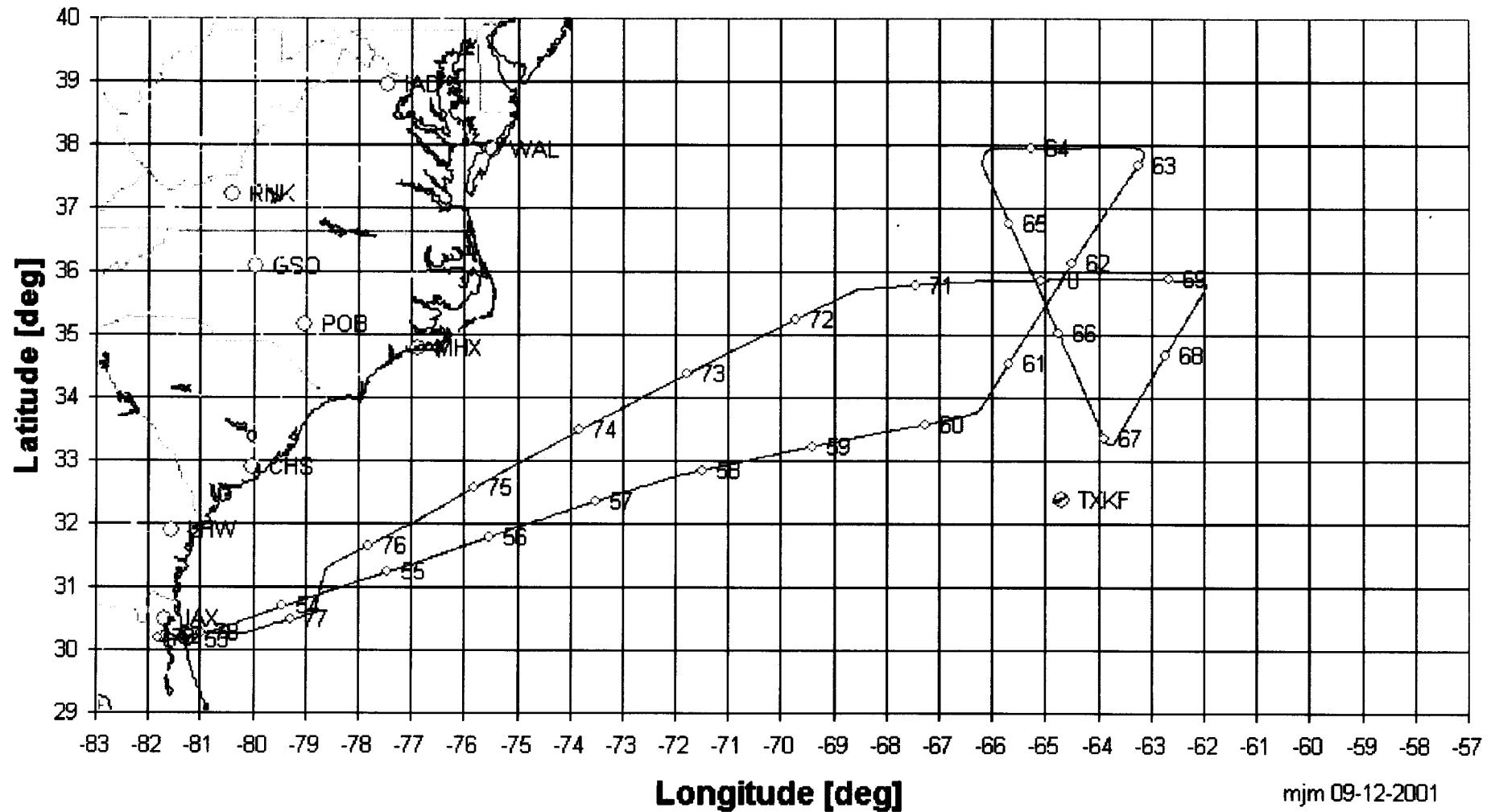


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## Flight Track - Latitude vs Longitude

CAMEX4 - ER2 20010910

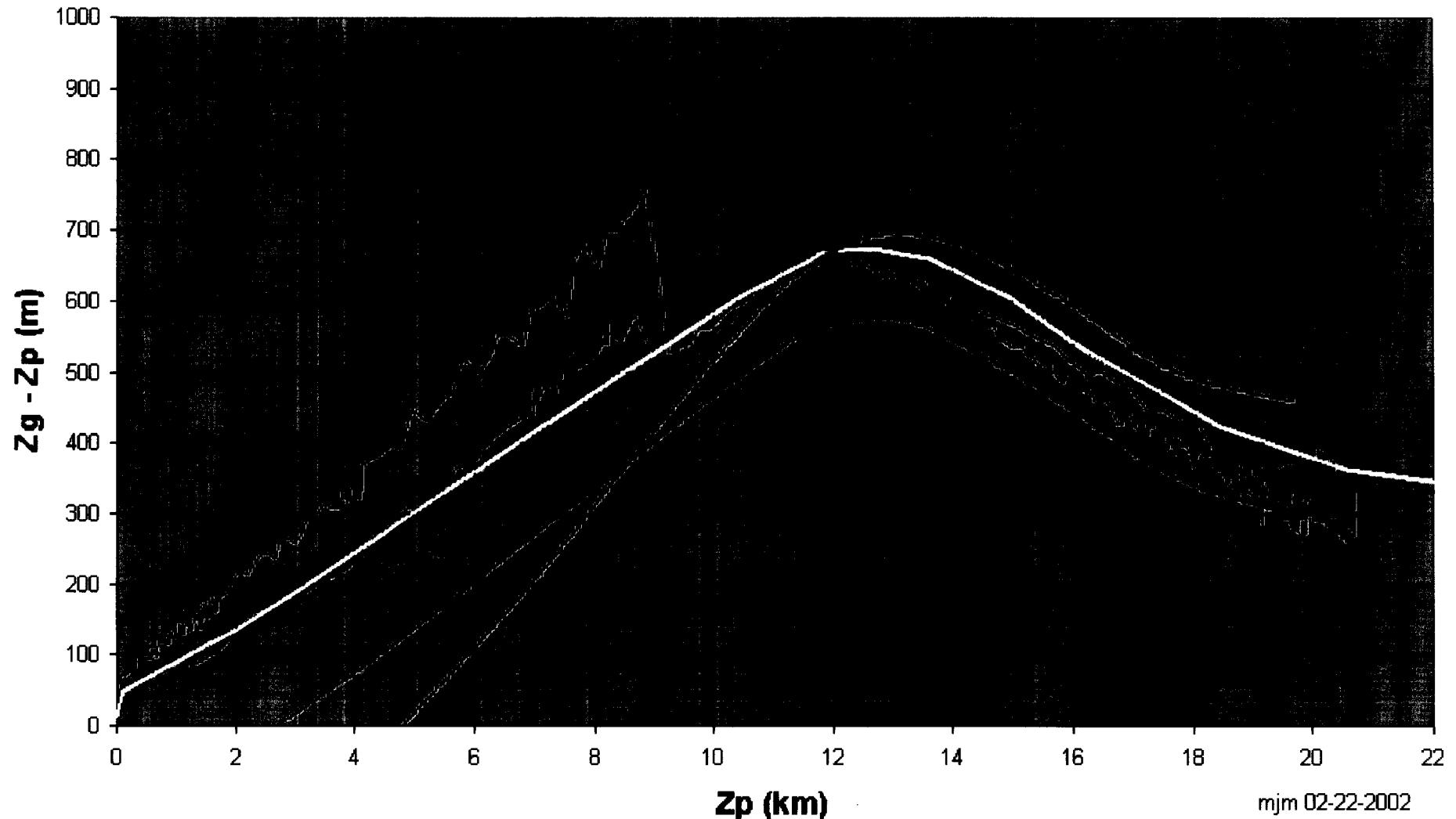
MTP



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**CAMEX-4 ER-2 2001.09.10 (Hurricane Erin)**

MTP

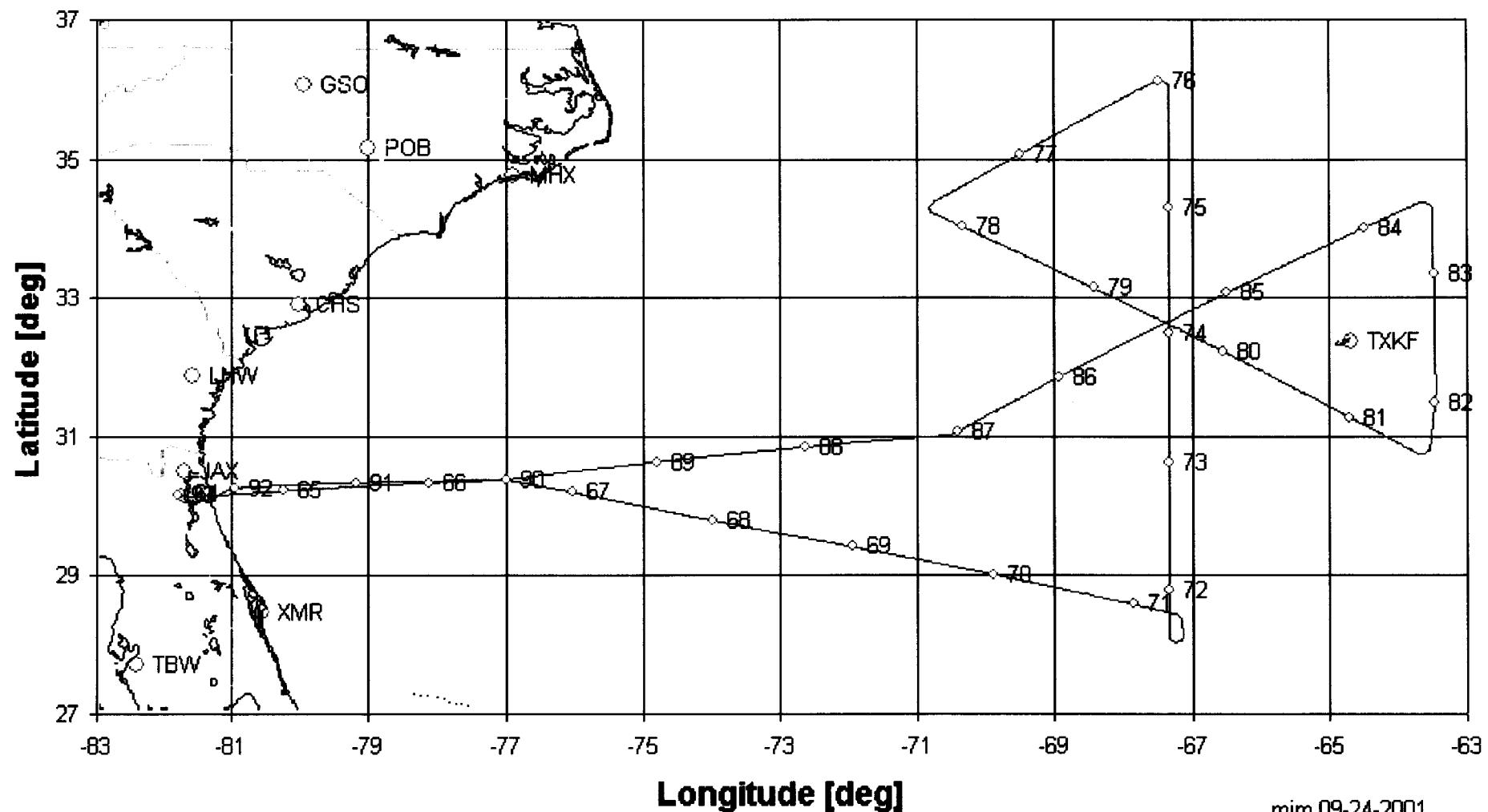


mjm 02-22-2002

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Flight Track - Latitude vs Longitude  
CAMEX4 - ER2 20010923

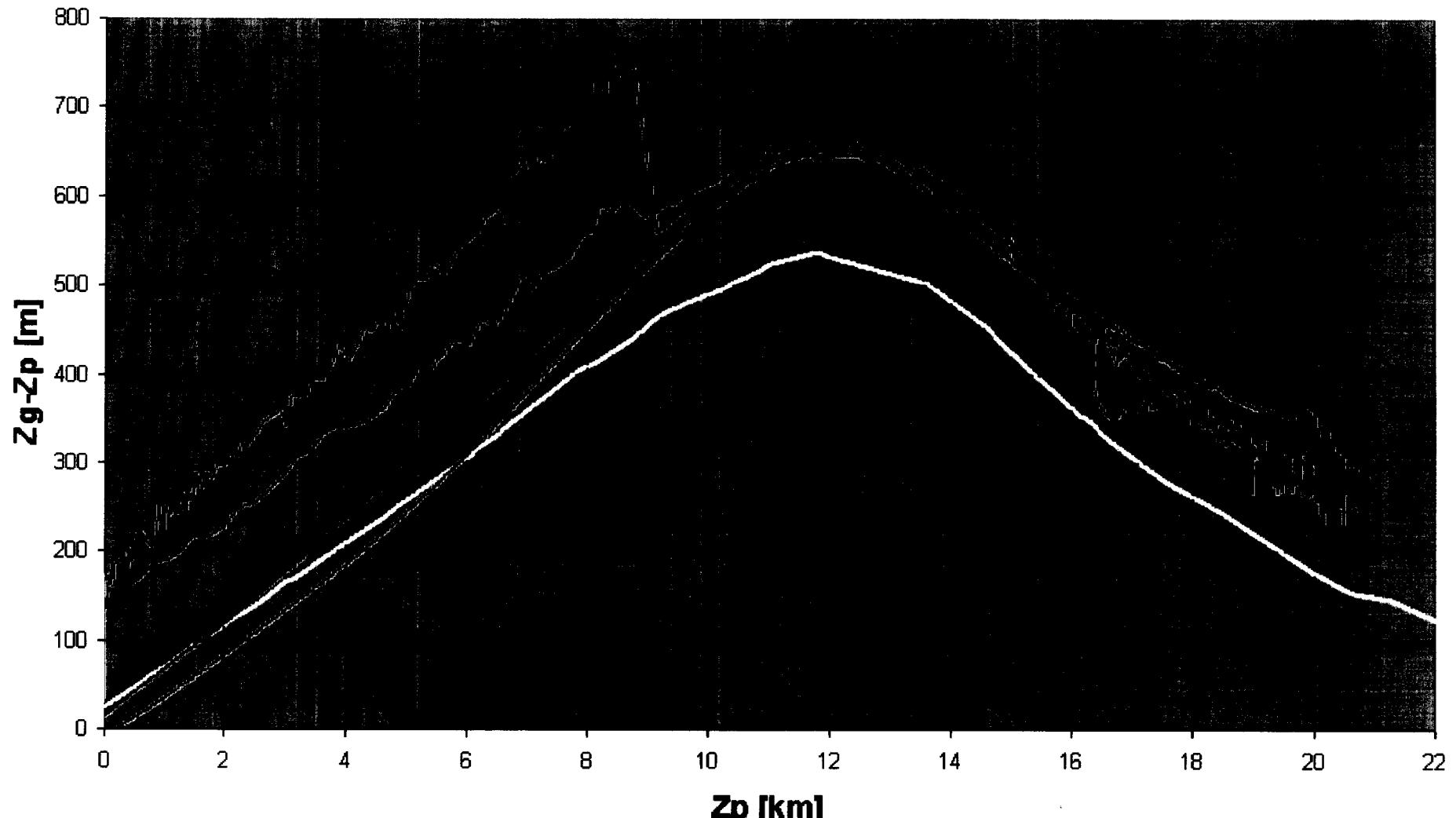
MTP



mjm 09-24-2001

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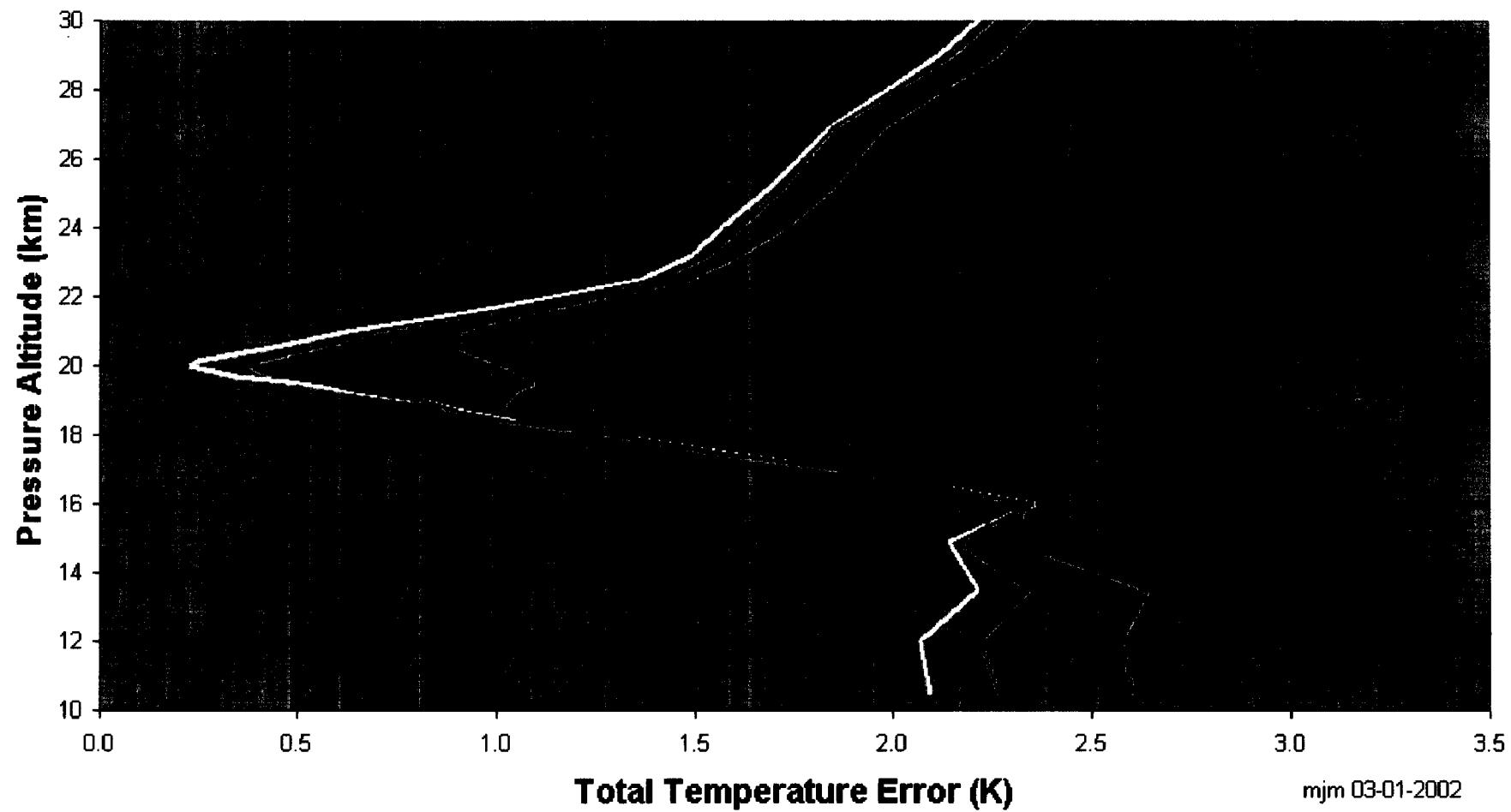
CAMEX-4 ER-2 2001.09.23 (Hurricane Humberto)



JPL

MTP

**Simulated ER-2 MTP Total Retrieval Error for Flight at 20 km**  
(Observables Calculated at 20.0, 19.9, 19.7 & 19.4 km using 196 RAOBs)



mjm 03-01-2002



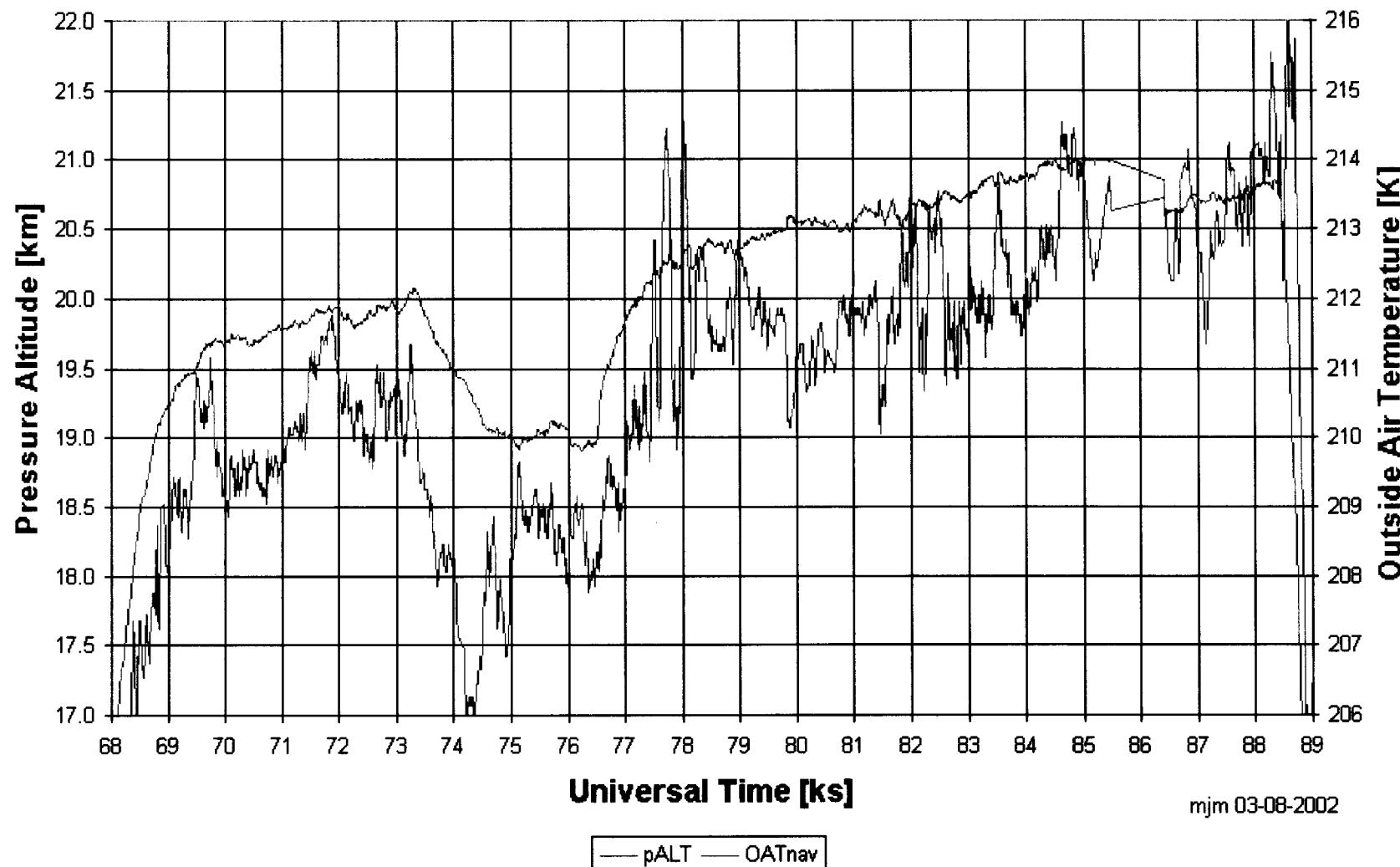
A 600 meter error in Zp significantly degrades MTP retrievals (green)

# **Microwave Temperature Profiler (MTP)**

**Some science results**

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**Pressure Altitude & Outside Air Temperature vs Universal Time MT**  
CAMEX4 - ER2 20010924



mjm 03-08-2002

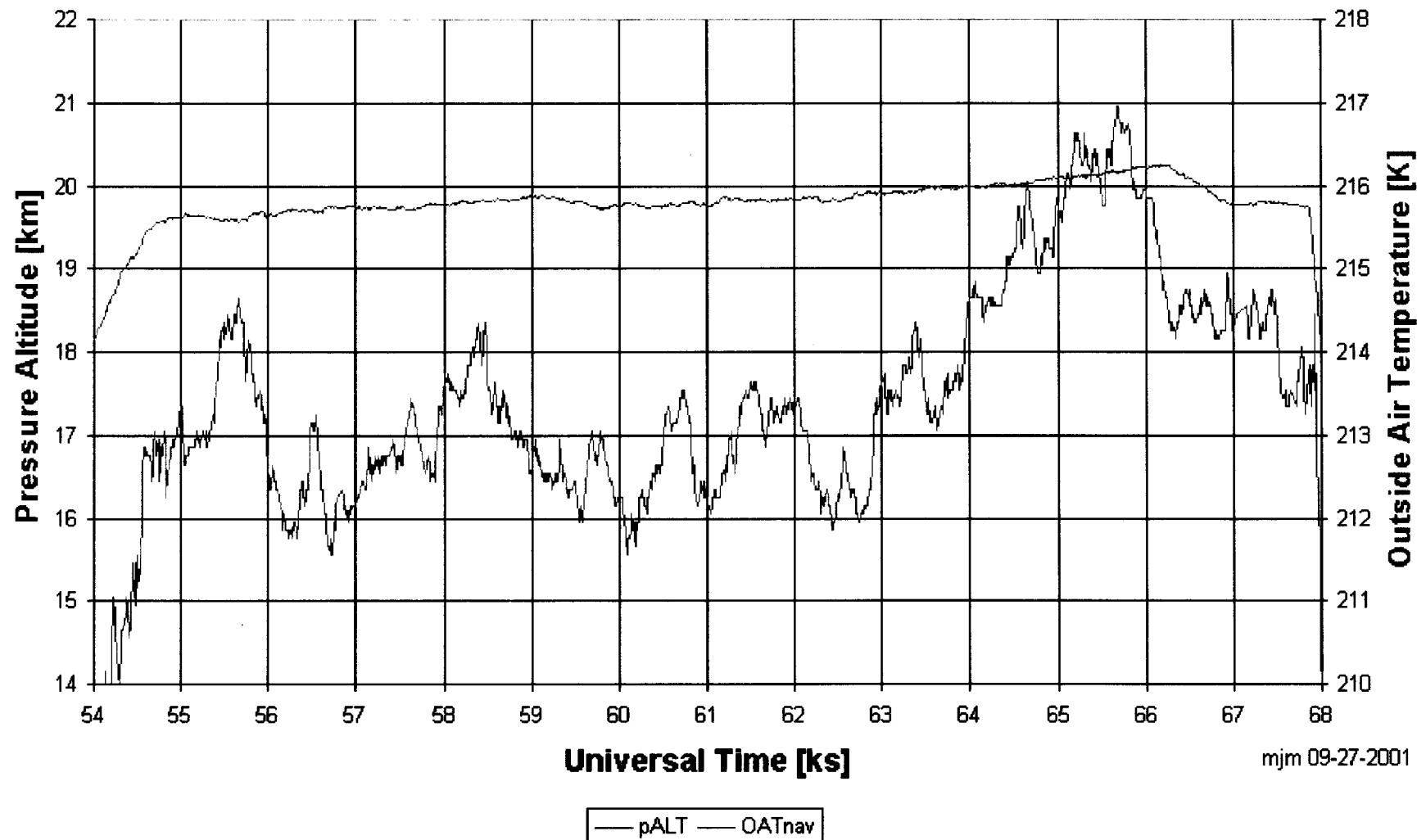
— pALT — OATnav

A goal for the MTP observations is to study mesoscale wave phenomena

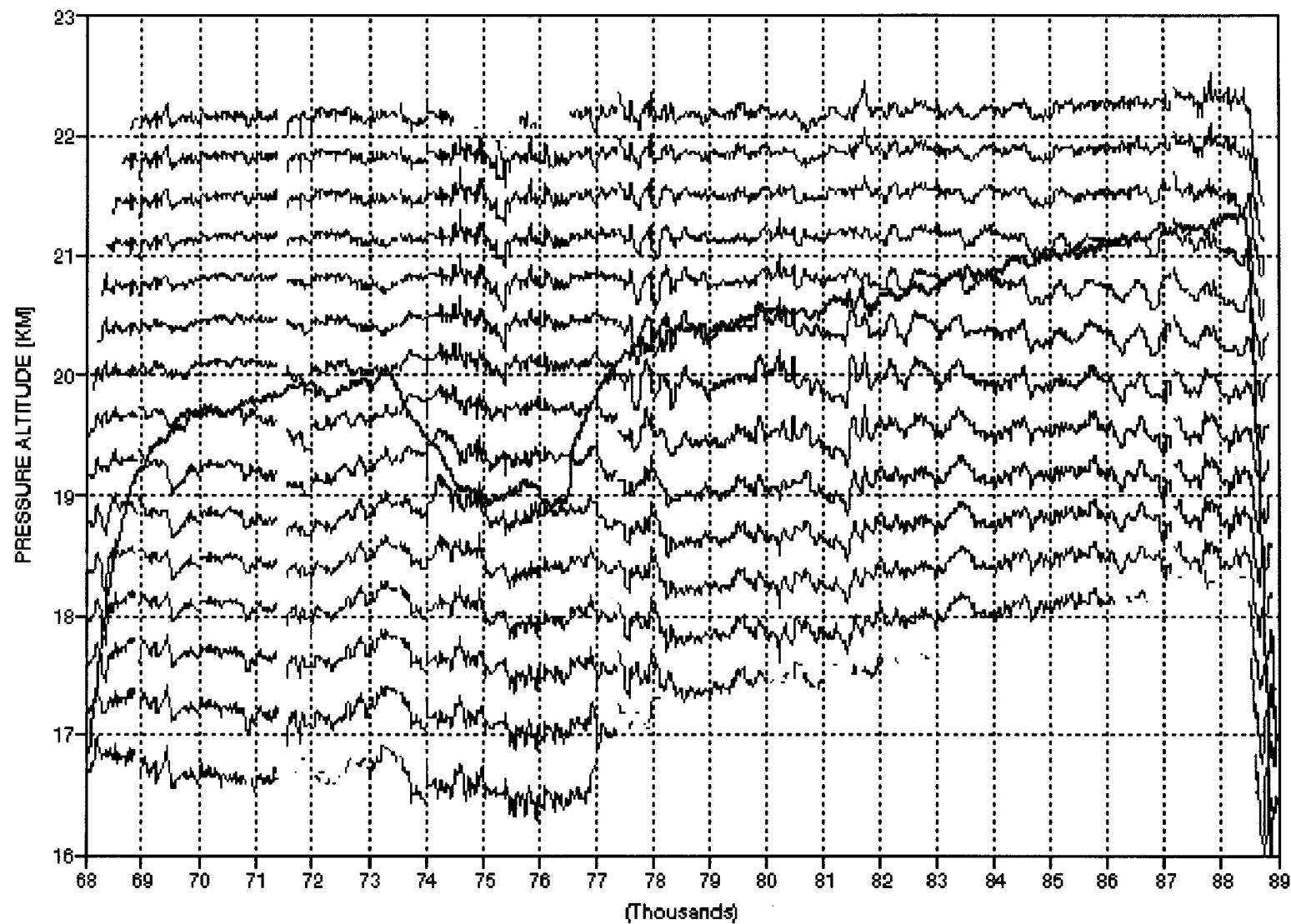
- Waves appear to be present in the MTP horizon TBs (77 ks & 82 ks)
- Mesoscale fluctuations appear to be greater than on transit flight (next slide)

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**Pressure Altitude & Outside Air Temperature vs Universal Time MTP**  
CAMEX4 - ER2 20010926



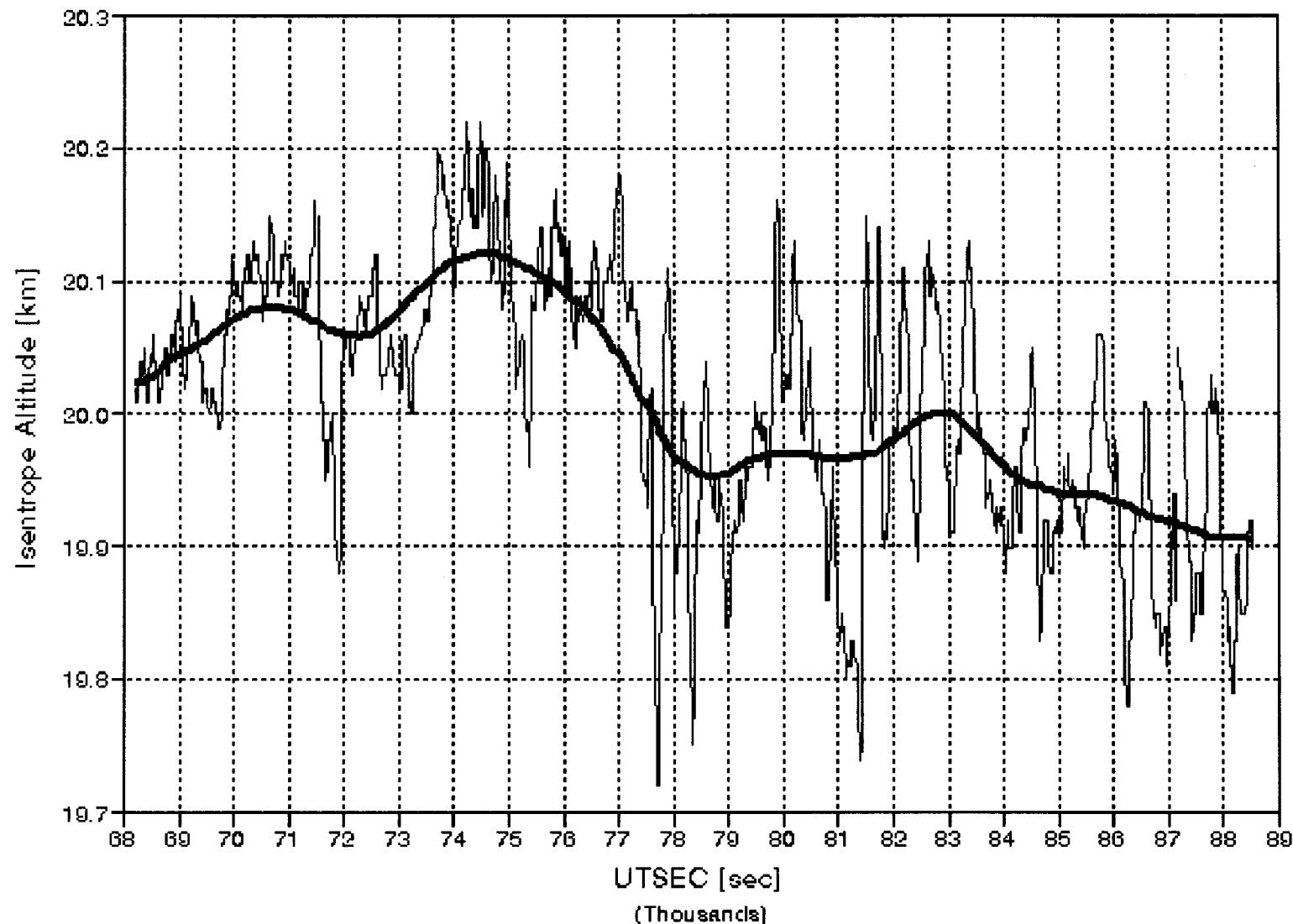
MTP Isentrope Altitude Cross-Section  
ER010924



MTP-derived isentrope surfaces for Hurricane Humberto flight of 2001.09.24

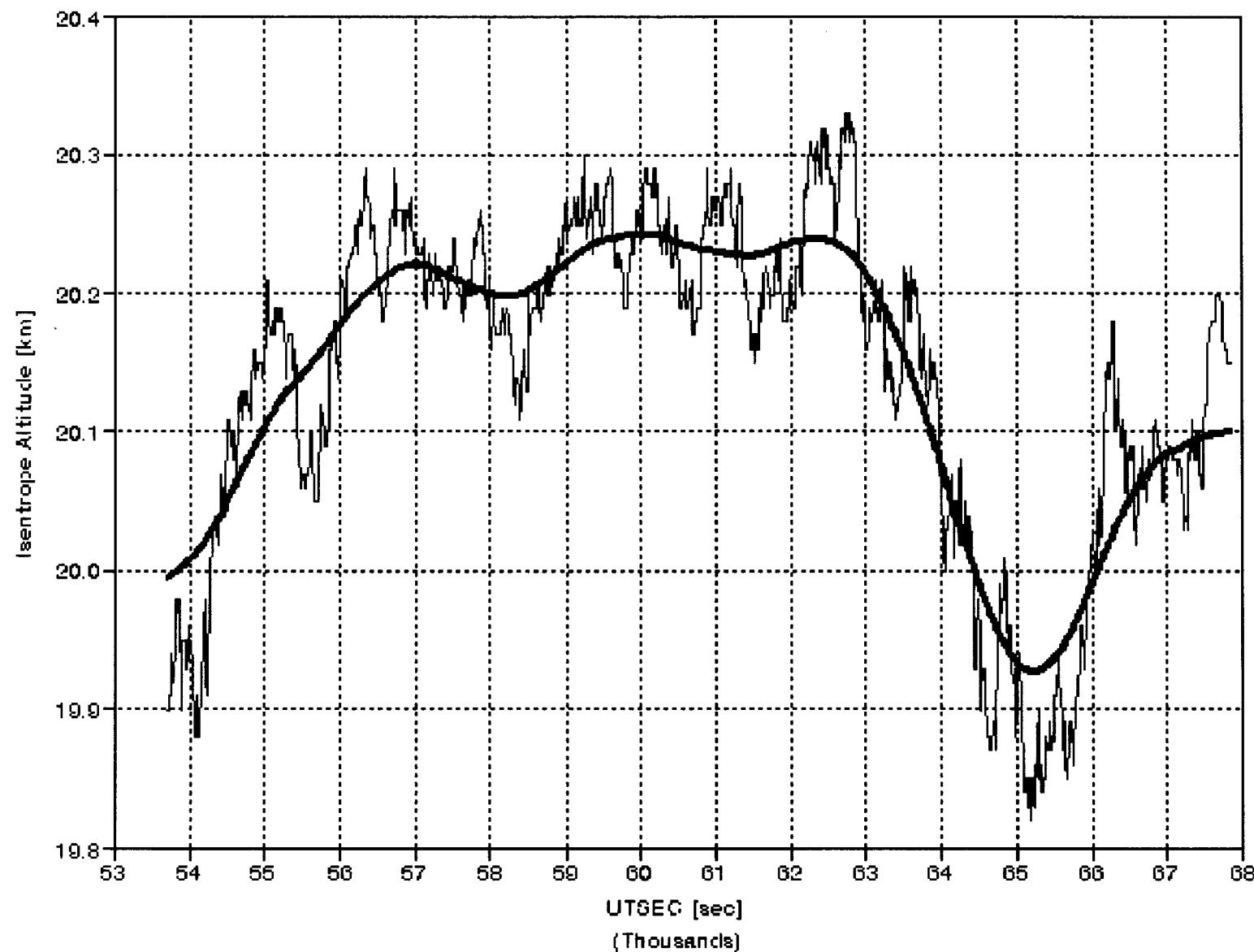
- Note low amplitude waves at ~77 ks and 82 ks

**ER2001.09.24, 490 K Isentrope**  
DOUBLE-BOXCAR 400 KM MOVING AVG



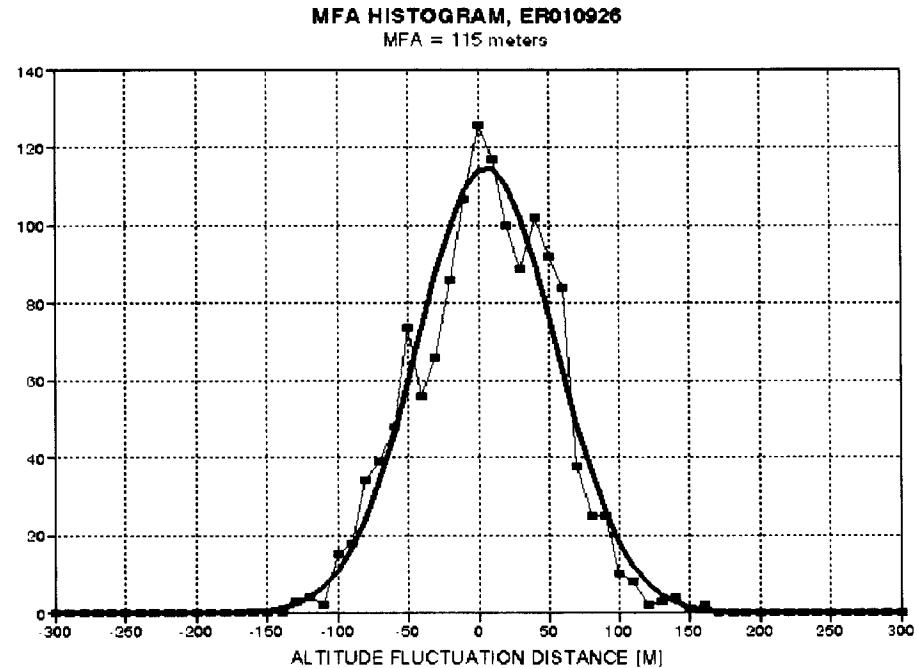
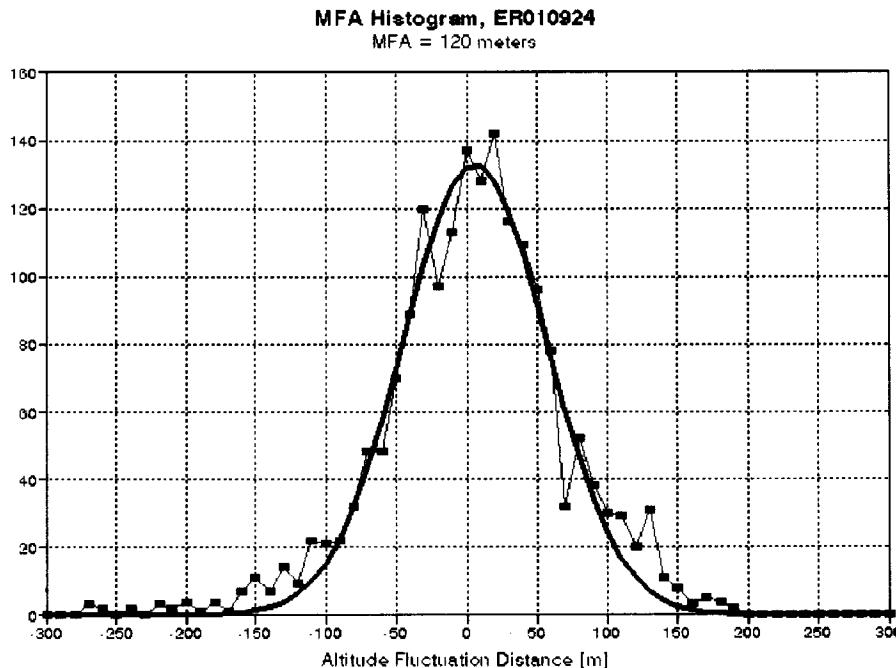
Focussing on 480 K isentrope clearly shows low-amplitude mesoscale waves over Hurricane Humberto; solid black trace shows synoptic scale isentrope surface

ER010926, 490 K Isentrope



There do not appear to be any mesoscale waves present in the ER-2 transit flight

# ER-2 Microwave Temperature Profiler (MTP)



The Mesoscale Fluctuation Amplitude (MFA) is the full-width at half-maximum of the histogram of mesoscale temperature fluctuations in meters. It depends on altitude, latitude, season and topography, and can be expressed as:

$$\text{MFA} = \left[ 137 - 1.61 \cdot \text{Latitude} + 97 \cdot \left[ 1 + \sin \left[ 2\pi \cdot \left( \frac{\text{DOY} - 292}{365} \right) \right] \right] \cdot \left( \frac{\text{Latitude}}{80} \right)^2 + 43.6 \cdot \text{Topography} \right] \cdot \left( \frac{58.85}{P(\text{mb})} \right)^{0.39}$$

Hurricane Humberto - 2001.09.24

Expect: MFA = 100 meters

Measure: MFA = 120 - 130 meters

Transit: JAX to DFRC - 2001.09.26

Expect: MFA = 118 meters

Measure: MFA = 115 meters

# **Microwave Temperature Profiler (MTP) Status**

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  - Based on RAOB comparisons, the required correction is:  $-1.51 \pm 0.36$  K
- Nav Data Recorder (NDR) Pressure Altitude (Zp) is *too low*
  - The error is 400-600 meters (~3-5 hPa) at 21 km
  - Procedure developed to reduce this error to <100 meters
  - Impact is to increase MTP retrieval error significantly if error is >100 meters



## **Report on DC-8 MTP Data and Data Analysis**

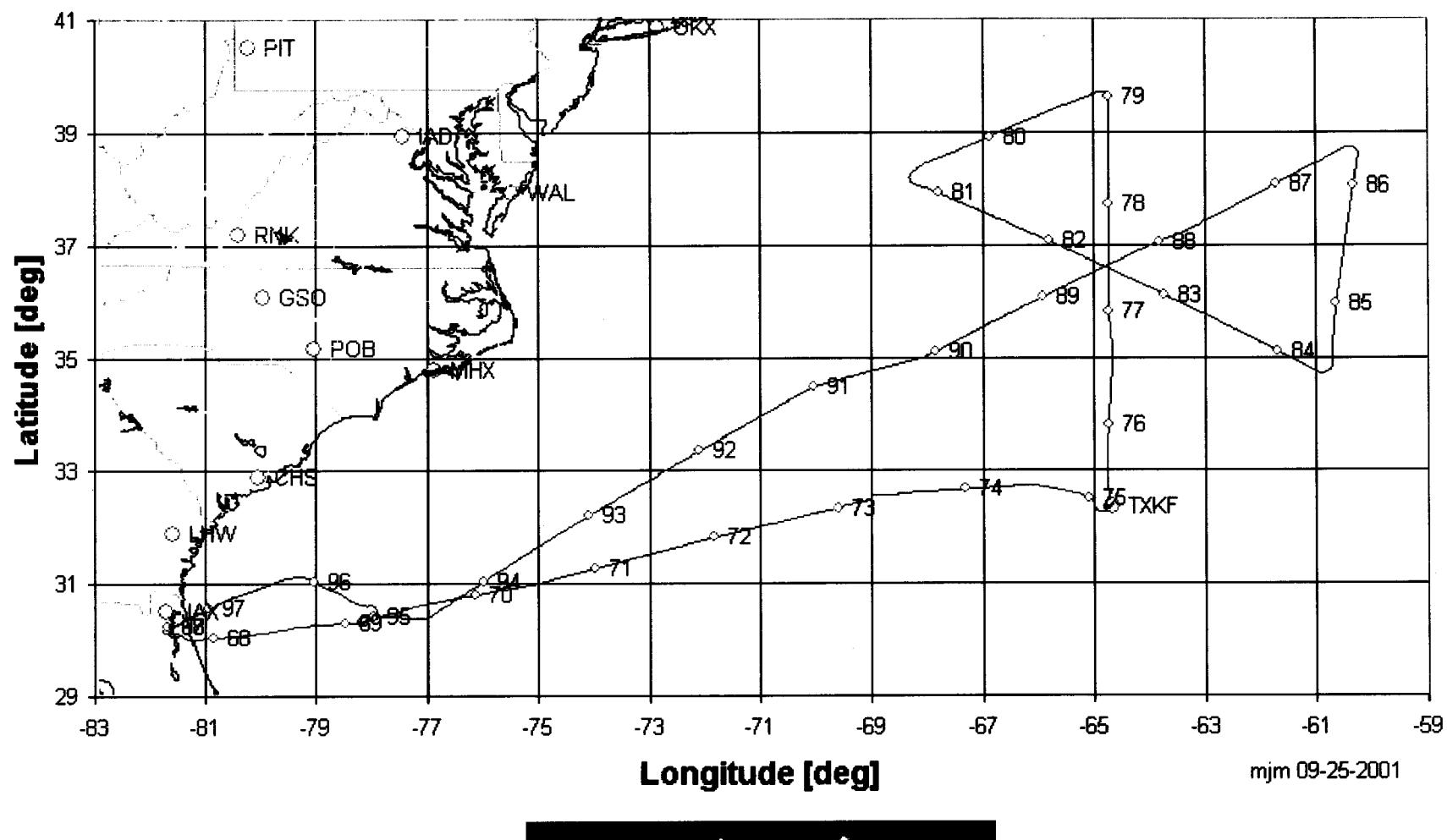
- Excellent data set, some interference but very much less than on ER-2
- Analysis not funded

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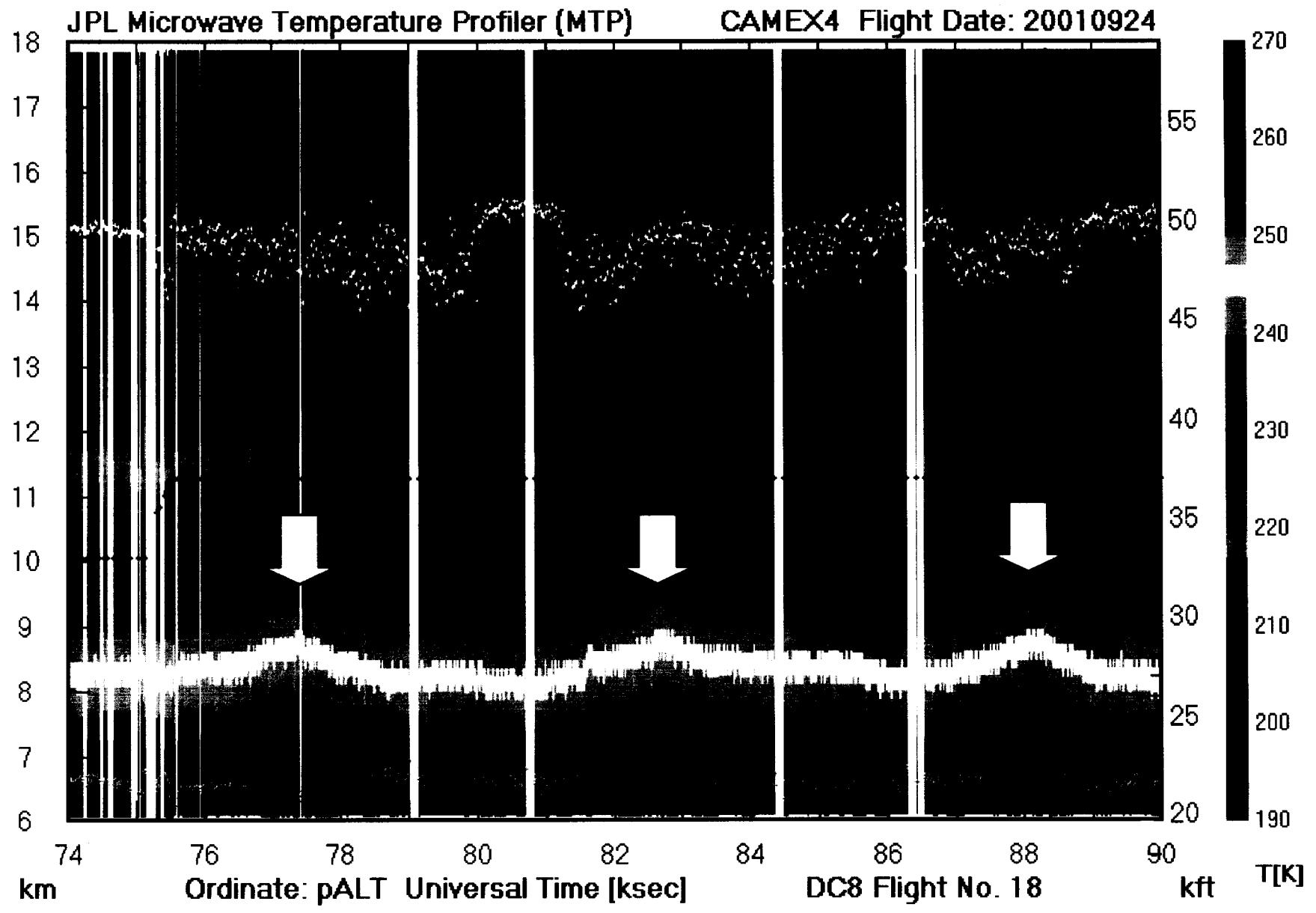
### Flight Track - Latitude vs Longitude

CAMEX4 - DC8 20010924

MTP



DC-8 MTP clearly sees a temperature anomaly associated with transects of Hurricane Humberto on 2001.09.23 and 2001.09.24 (next slide)



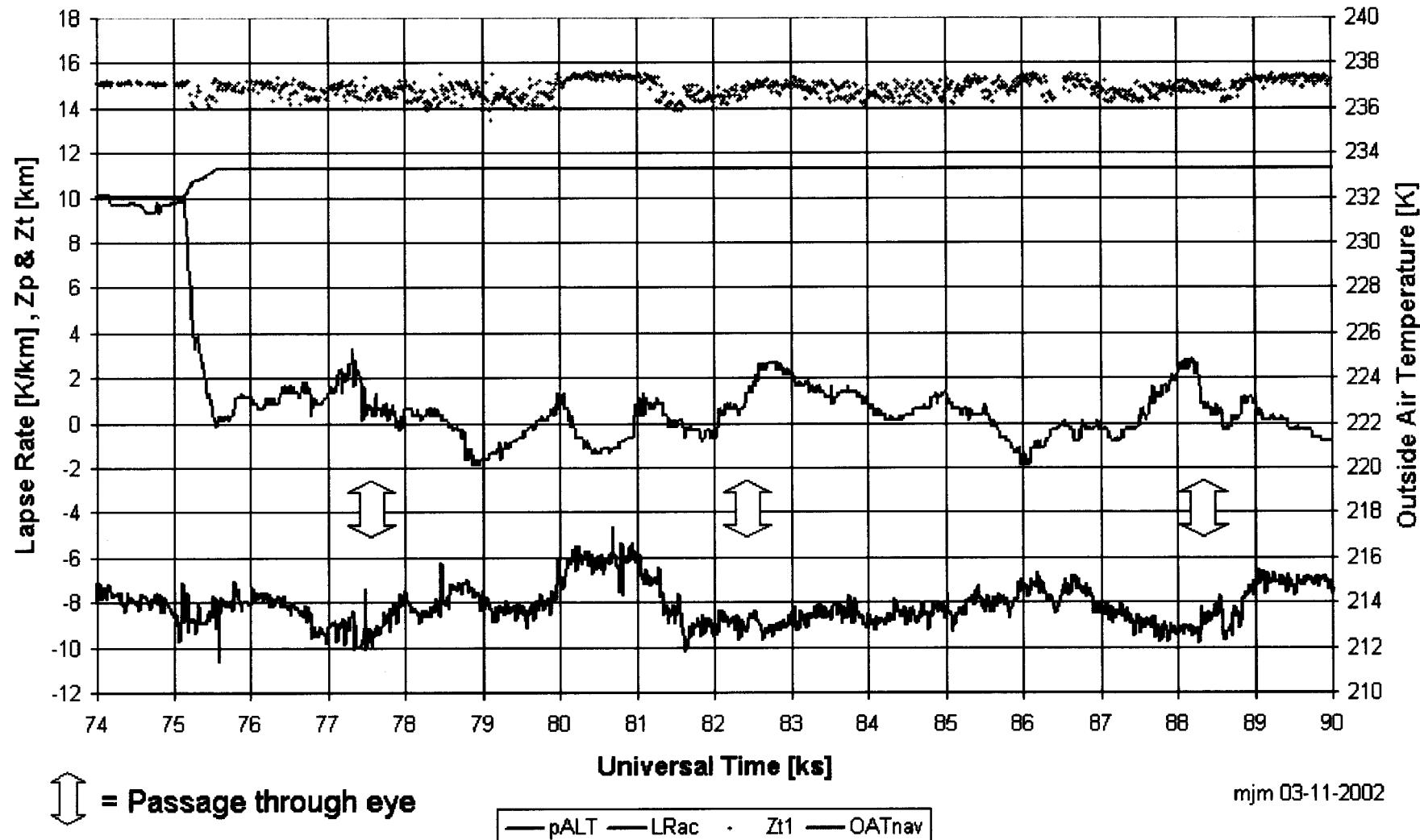
= Temperature anomaly associated with passage through the eye  
of Hurricane Humberto on 2001.09.24

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# Lapse Rate, Zp, Zt & OAT vs Universal Time

CAMEX4 - DC8 20010924

M1



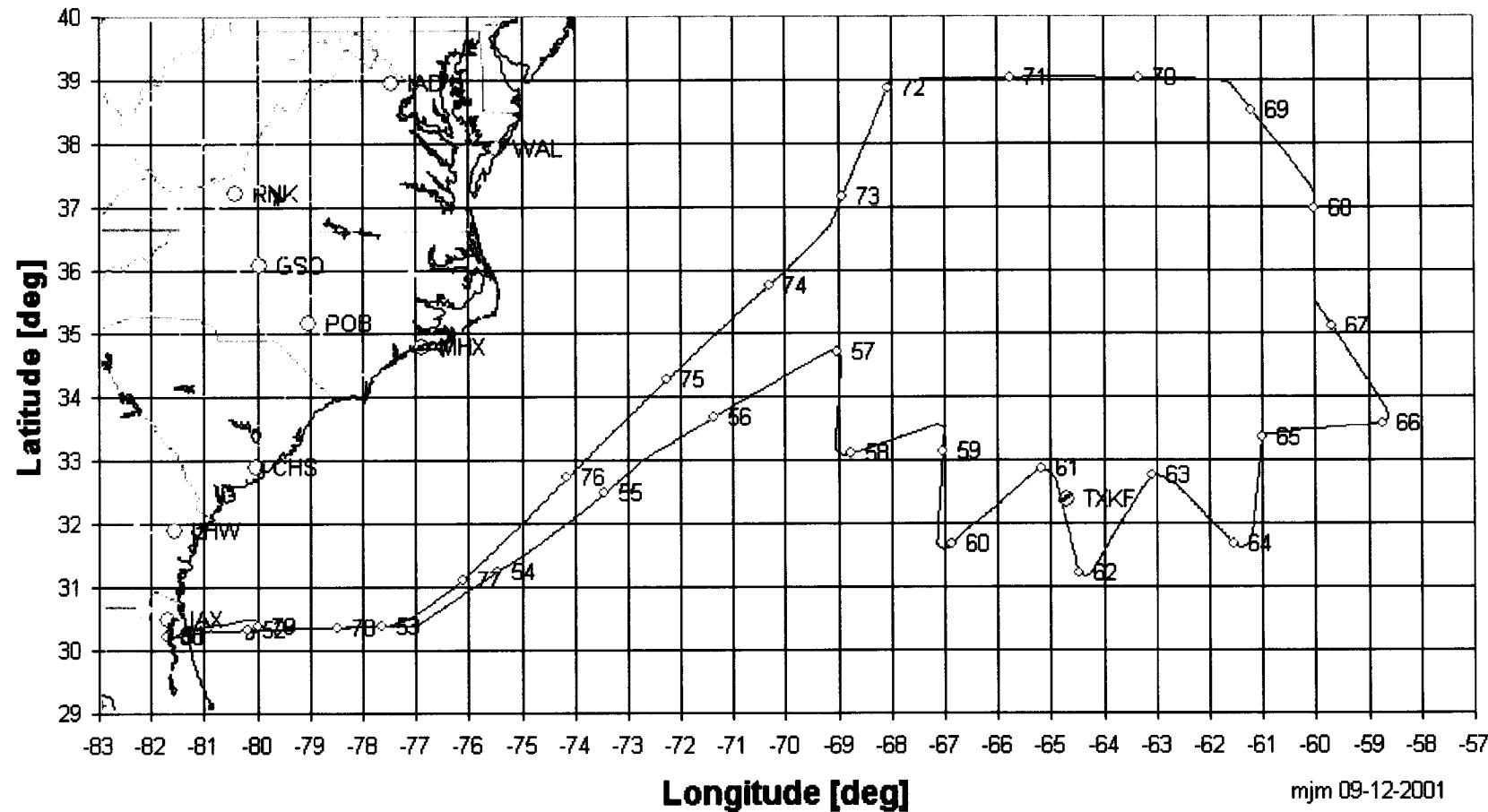
Transects of Hurricane Humberto are associated with ~3 K temperature anomaly and decrease in the lapse rate to near dry adiabatic (~ -10 K/km)

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## Flight Track - Latitude vs Longitude

CAMEX4 - DC8 20010910

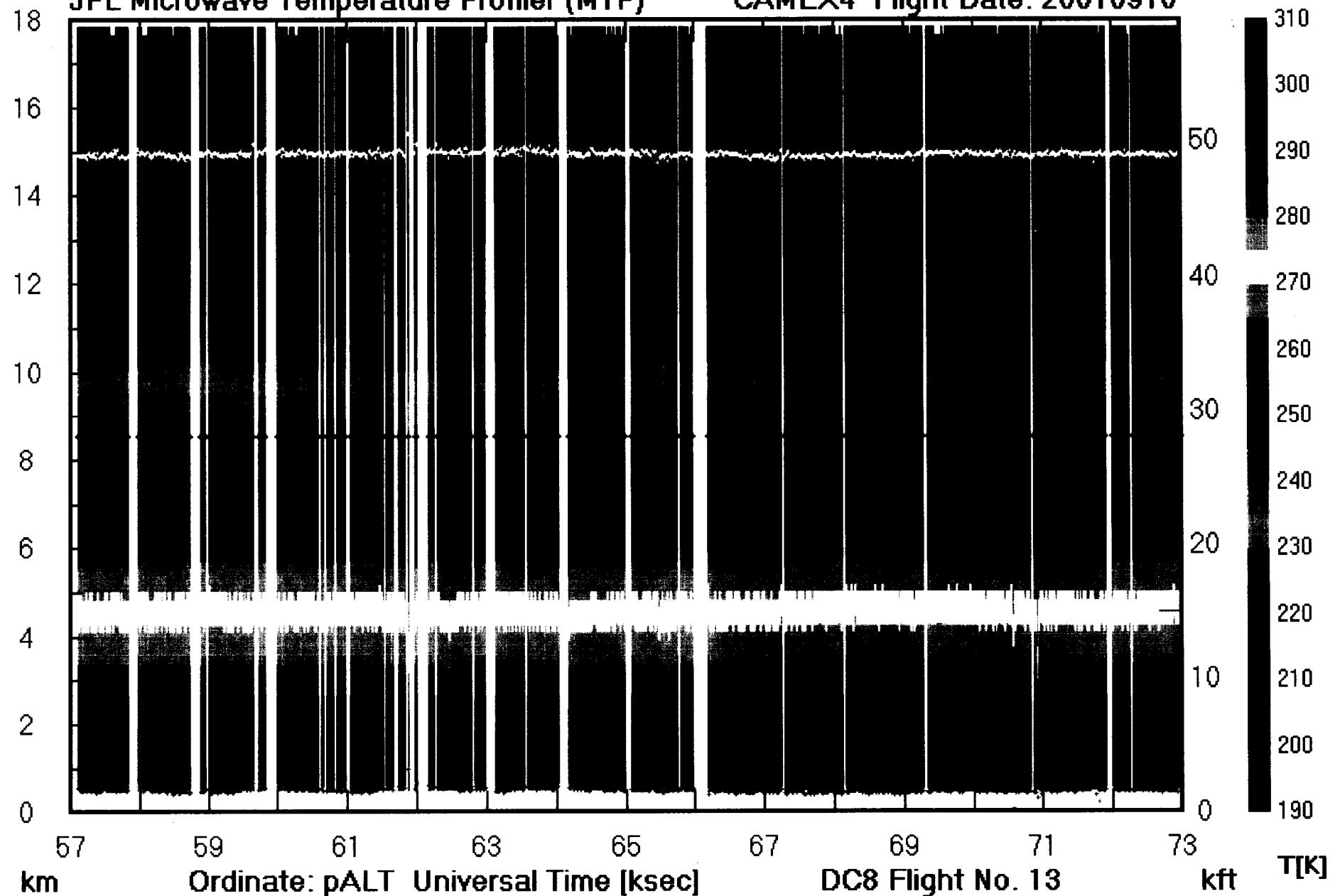
MTP



In contrast to the Humberto flights, the DC-8 circumnavigation of Hurricane Erin on 2001.09.10 shows very little variation in temperature and lapse rate

JPL Microwave Temperature Profiler (MTP)

CAMEX4 Flight Date: 20010910

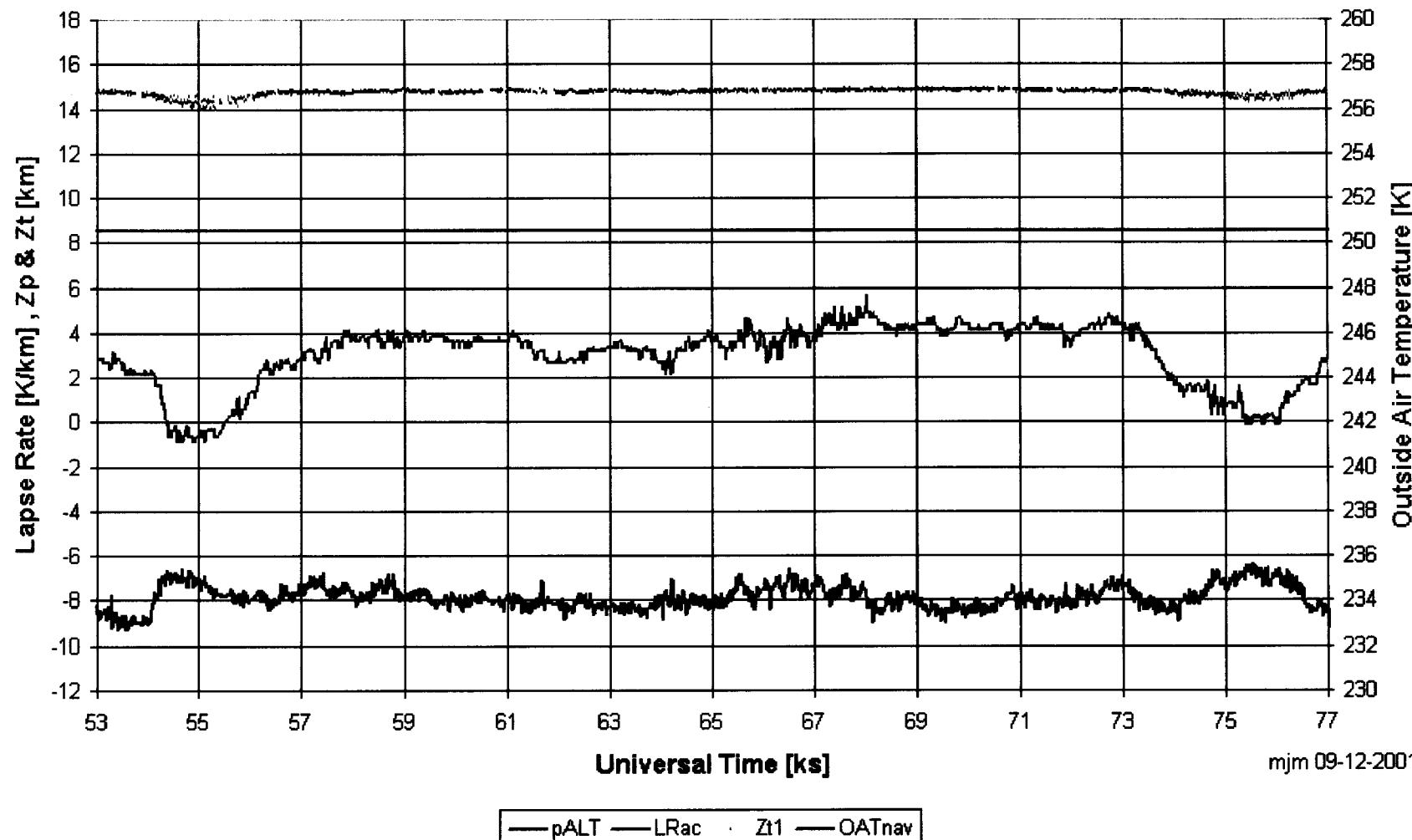


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# Lapse Rate, Zp, Zt & OAT vs Universal Time

CAMEX4 - DC8 20010910

MTP



Note increase in temperature and decrease in lapse rate as Hurricane Erin is approached (~55 ks) and departed (75 ks).

# **Plans for FY'02 and FY'03**

## **FY'02 Plans:**

- Complete analysis of ER-2 MTP data
- Submit to archive within 2 months
- Collaborate with other CAMEX-4 PI's as much as possible
- Carry out independent research to study wave phenomena associated with convection (with collaborator, Dr. Joan Alexander, CoRA)

## **FY'03 Plans:**

- No funding requested for FY'03; therefore, no plans

## **Acknowledgements:**

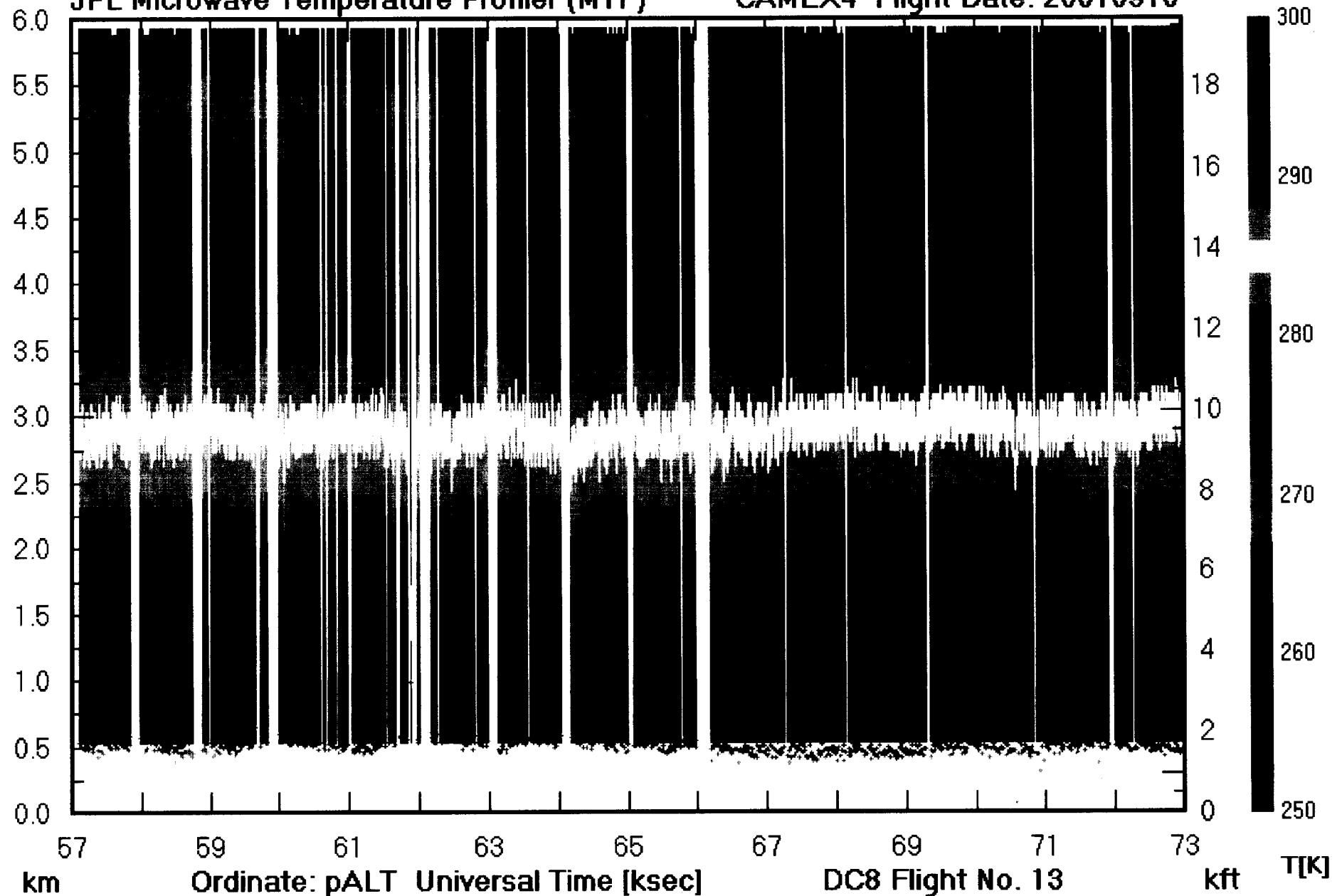
- Dr Ramesh Kakar for ER-2 support, Bruce L Gary for help with data analysis, and Richard Denning for instrument support.

# **Microwave Temperature Profiler (MTP)**

**Backup**

JPL Microwave Temperature Profiler (MTP)

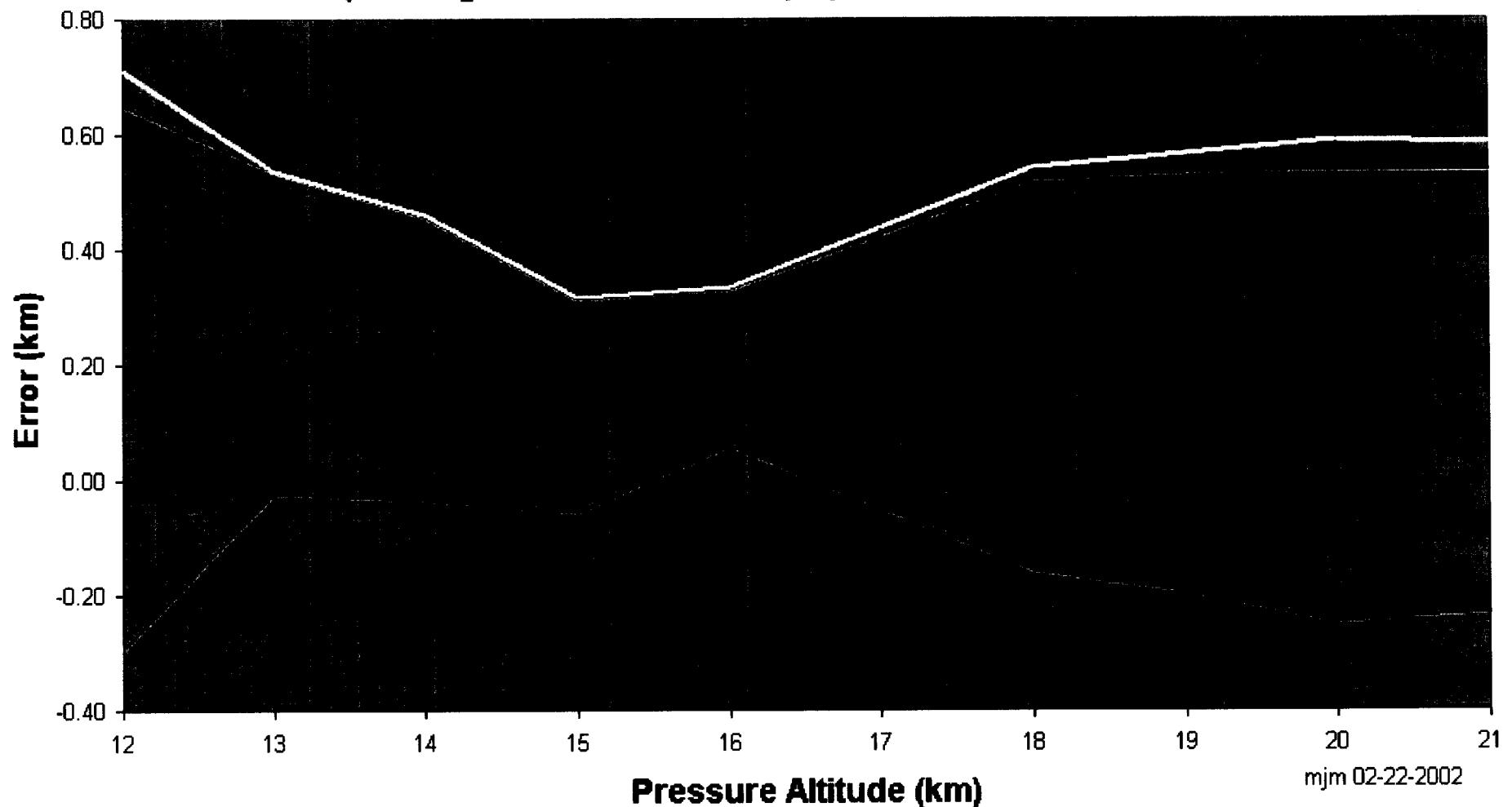
CAMEX4 Flight Date: 20010910



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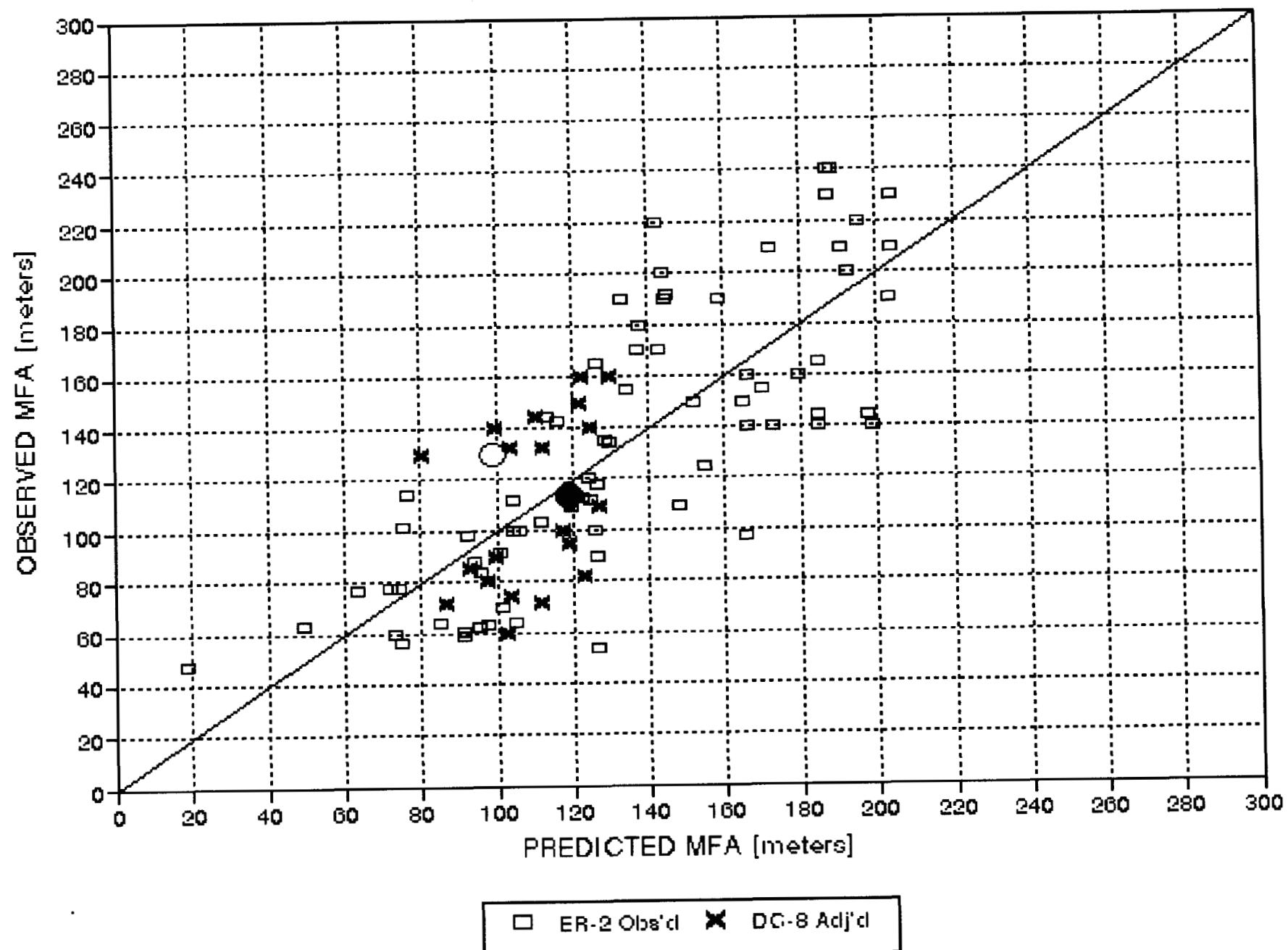
Tropopause<sub>MTP</sub>-Tropopause<sub>RAOB</sub> Errors vs Pressure Altitude  
Based on Simulated Retrievals of 194 Tropical Radiosondes  
(Average Radiosonde Tropopause at ~15.5 km)

MTP



mjm 02-22-2002





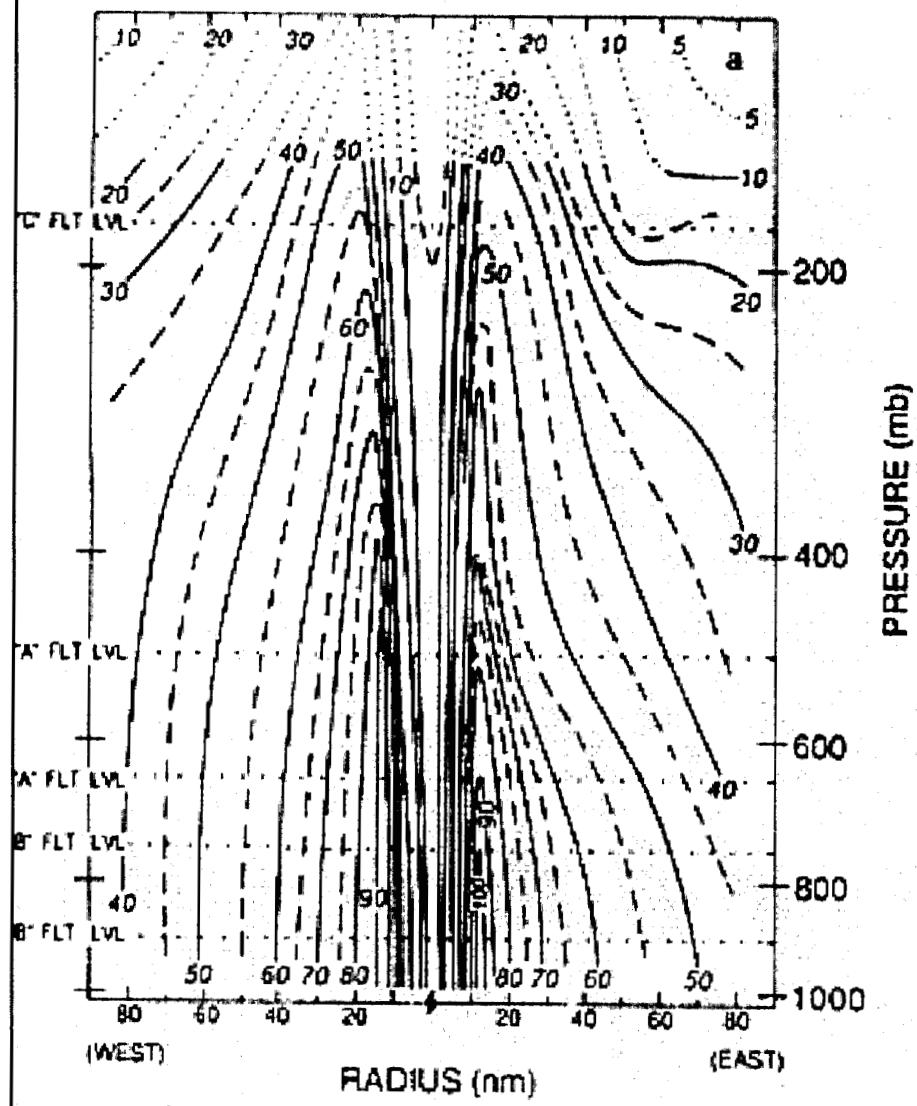


Fig. 2.6 Vertical cross sections of (a) azimuthal wind (kt), and (b) temperature anomaly ( $^{\circ}$ K) in Hurricane Hilda of 1964 (Hawkins and Rubsam 1968).

